MEMOIRS

OF THE

AMERICAN ACADEMY

OF

ARTS AND SCIENCES.

NEW SERIES.

VOL. III.

CAMBRIDGE AND BOSTON:
METCALF AND COMPANY,
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FOR THE YEAR BEGINNING MAY 27, 1848.

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EULOGY

ON

JOHN PICKERING, LL. D.,

PRESIDENT OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES.

BY DANIEL APPLETON WHITE,
FELLOW OF THE ACADEMY.

(*Delivered before the Academy October 28th*, 1846.)

MR. PRESIDENT, AND GENTLEMEN OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES, —

AMONG all the works of God, I know of no object of contemplation more delightful than a beautiful human character, pure and lovely, ennobled by Christian virtues, and adorned by the accomplishments of mind. Such was eminently the character of our late beloved associate and President, JOHN PICKERING, whose death we have been called to deplore, and whose distinguished worth we have come together to contemplate and honor. The reluctance which, as some of you know, I felt at becoming your organ on this affecting occasion, arose from my conscious inability to do justice to his profound erudition; but the charm of his character overcame my reluctance, and if I can succeed in drawing a faithful portrait of his life and virtues, I shall rely on your goodness to pardon the imperfect sketch I may give of his talents and learning.

That noble-hearted man, the late Judge Lowell, in commencing

his eulogy on the first President of the American Academy, recognizes the obligation "to trace the path of the great, the virtuous, and the wise, through all their exertions for the benefit of mankind, and to portray their characters as an example to the world." This, doubtless, is the highest purpose of eulogy, and most worthy both of the living and the dead. The memory of great and good men is most truly honored by that which, at the same time, most benefits the world, — the study and practice of their virtues.

You will allow me, therefore, Gentlemen, in seeking to pay this true honor to the memory of one who so richly deserved it, whose life was so invariably virtuous, and who rendered himself so eminently wise and useful, to give especial attention to those virtues and exalted principles which enabled him to achieve his unsullied fame, and which may enable others, stimulated by his example, to pursue a like honorable career. Such a manner of proceeding on this occasion well accords with the high ultimate design of the American Academy ; — "to cultivate every art and science which may tend to advance the interest, honor, dignity, and happiness of a free and independent people." Of all arts conducing to this great end, the most important, certainly, is the art of human improvement, and the most excellent of sciences is the science of a good life. And both are best studied from original models of excellence. Biography, still more than history, is philosophy teaching by example the lessons of wisdom ; but, to fulfil its office, it must teach in the spirit of philosophy, and unfold the means and inculcate the principles upon which progress in excellence essentially depends. The life which is now presented for our contemplation, if exhibited with that truth and simplicity which were so remarkably its ornaments, would beautifully illustrate the lessons of wisdom, and make her ways as clear to the studious mind, as

they are pleasant to the upright in heart. We care little for the mere possession of talents or genius; real merit is above them both. And where shall we look for one who in the meritorious use of talents is greater than our departed friend? Such a life as his cannot be traced too minutely, from its dawn to its close. Genius and eloquence have already, on various occasions, bestowed a rich and glowing eulogy on the learned jurist, the man of science, of letters, and of worth, leaving us, in echoing the voice of praise, little more to do than to enforce its justness, and to gather what instruction we may from the virtues which have called it forth.* The simple truth, Gentlemen, bestows the highest eulogy on our lamented President, while it affords us the truest consolation and the best instruction.

John Pickering was the eldest of ten children of the late Colonel Timothy and Rebecca White Pickering, and was born on the 7th day of February, 1777. His ancestors were of a most worthy character. The first of them known in this country was John Pickering, who was one of the early settlers of Salem, and in 1642 bought of Sir George Downing's father the farm on Broad street in that town, which has ever since descended in the male line of the family, and always, except in a single instance, has been owned by a John Pickering, as it still continues to be. On it stands the ancient and picturesque mansion, the late summer residence of our deceased friend, who by his skilful arrangements converted the greater portion of the farm into a beautiful and flourishing village.

Colonel Pickering was a vigilant and devoted father, but his

* See the noble tribute to the memory of Mr. Pickering, contained in the *Law Reporter* (Vol. IX., p. 49), from the gifted pen of Charles Sumner, Esq.; also his admired *Address before the Phi Beta Kappa Society of Harvard University, at their Anniversary, August* 27, 1846.

whole soul was so absorbed in his country at that alarming crisis of her affairs, that he could bestow but a transient attention upon his son's early culture. Fortunately for this son, he was, like Sir William Jones, whom in other respects he so strongly resembled, blessed with a mother in every way qualified to fulfil the duties of both parents. In his intelligent, docile, and sweet disposition she beheld the image of her own gentle spirit, and she could not fail in all her intercourse with him to exert a propitious influence upon his opening mind and character. He had an excellent uncle, too, the Honorable John Pickering, who lived in Salem, and who indulged for him all the feelings of a parent. John and Timothy Pickering were only brothers, and their souls were knit together in the closest friendship. Both were zealous Whig patriots, renowned for their integrity and steadfastness. John was graduated at Harvard College in 1759, four years before his younger brother, and was one of the original founders of the American Academy. He sustained various important public trusts, and at the time of his nephew's infancy was Speaker of the House of Representatives of Massachusetts. They had seven sisters, all of whom were married and had families, some of which were highly distinguished. Young John, bearing the favorite ancestral name, and possessing uncommon attractions, was the object of observation as well as interest, without being exposed to those fond and admiring attentions which are so apt to foster vanity and selfishness.

As it is our desire to show from his example how characters like his may be formed, where natural gifts like his are bestowed, and how human excellence is best attained, whatever may be the endowments of nature, we shall freely avail ourselves of the most authentic information we possess, without using the family corre-

spondence, of the early development of his faculties and the progress of his education. There are four periods which deserve distinct attention; — the five or six years of childhood, before he went to any school; his years at school; his four years in college; and his four following years abroad.

The first of these periods, though so little thought of generally, was to him, perhaps, next in importance to his college life, for in it was laid the foundation of his character and intellectual habits. Providence appears to have ordered the circumstances of it better for his improvement than human wisdom would have done. He was in no common degree qualified by nature, both in his physical and mental constitution, for self-direction and self-cultivation. His senses, particularly his sight, hearing, and touch, were acute and delicate; so, too, were all his faculties and feelings. He had a curiosity all alive, together with a memory quick and retentive. His mechanical ingenuity was as early manifested as his intellectual vigor. Happy was it for him, that he was exposed to no luxurious gratifications or excessive indulgences of any kind. Happy, too, probably, that he had no teacher but his mother, aided by the influence of his admirable father, and that he was in so great a degree left to be his own teacher.

During this period, his father, being attached to the Revolutionary army, had no fixed place of abode for his family, and they resided successively at Salem, Philadelphia, Newburgh, and then again at Philadelphia and in its vicinity. It was not till their second residence at Philadelphia that a good school could be obtained for John, which was a subject of frequent regret with his mother, but doubtless all the better for him. His lively curiosity and love of knowledge had become remarkable before he was two years old, evinced particularly by a continued attention and interest in his observation of

things. Nearly at the same time he commenced his philological career. Of his own accord he took it into his head to learn to read; and, at the age of two years, he could repeat the letters of the alphabet, and in speaking would readily join adjectives and verbs to his nouns. Before he was five years old, he could read without spelling, and spell without book, rarely missing a word which he had once read, however little affinity the letters might have to the sound. Such was the self-taught infant philologist.

We allude to these facts, not as being very wonderful in themselves, but as illustrating his natural powers and turn of mind, as well as his intellectual habits. His early devotion to learning led directly to those habits of observation, attention, and application, which were among his greatest advantages as a scholar. Equally fortunate was he in the early development of his affections and his moral nature. Besides the kindest care, he received the most judicious religious nurture, and constantly enjoyed the influence of examples which tended to produce in him the generous and noble virtues. It was perfectly natural that he should become what he was, truly magnanimous, and one of the most unselfish of human beings.

Thus prepared by himself, under the eye of his mother, he entered his first school at Philadelphia when he was about six years of age. His aptitude for wisdom and goodness, as well as for learning, had already inspired entire confidence, and disposed his parents to seek for him the best advantages of education. At this school, in addition to the usual English exercises, he attended to the French language, and pursued his studies with so much ardor and closeness of application, that some relaxation became necessary for his health. With a view to this, his father, in 1786, sent him on a visit to his uncle and other friends in Salem. He took only his French books with him, expecting soon to return. But it was

otherwise ordered. His uncle, who had now retired from public life, and was living on the family estate with a widowed sister and her only daughter, never having been married himself, became so attached to his beloved nephew, that he could not consent to part with him. Without formally adopting him, he ever after treated him as a son, and never was any parent more blessed in an own son.

John, thus made a fixed resident in Salem, at the age of nine years, soon resumed his studies with renewed health and energy. His character, having received such a powerful impulse in the right direction, could not fail to be carried forward in strength as well as excellence under the somewhat sterner influences which were now brought to bear upon him. In his uncle, alike dignified, wise, and affectionate, he found the best of domestic guides. His master in the Latin Grammar School was Belcher Noyes, an experienced teacher, and a man of some classical learning, as it would seem from a Latin grammar of which he was the author. His writing-master was Edward Norris, of whom he took lessons every day, for some length of time, with complete success. He was remarkable for his handwriting before he left Philadelphia, and it deserves notice here as one of his distinguished literary accomplishments. The handwriting, it has been said, indicates the writer's character. In him, certainly, both were alike clear, simple, and beautiful. Nothing perplexing was ever found either in his chirography or his character. The rank which he speedily attained as a classical scholar was high, as might be inferred from a fact related by a venerable gentleman, now living, — which deserves remembrance, too, as having served to swell the tide of good influences then bearing upon him. When President Washington visited Salem, in 1789, young Pickering was placed at the head of the Latin school in the procession on that occasion. What more powerful incentive to all

that is good and great could he have received, than the honor of thus meeting the saviour of his country and his father's friend?

Thomas Bancroft, a true scholar and gentleman from Harvard College, afterwards the distinguished Clerk of the Judicial Courts in Essex county, succeeded Mr. Noyes in the Latin Grammar School, and completed Mr. Pickering's preparation for the University. In this excellent instructer he found a no less excellent friend, for whom he cherished a high regard. But, though fitted for college by Mr. Bancroft, he was offered for admission by his father, who took the liveliest delight in his son's character and scholarship, and came from Philadelphia, probably on purpose to enjoy the pleasure of presenting him to the University at Cambridge. After being honorably admitted, in July, 1792, he accompanied his father to Philadelphia, where he passed a happy vacation.

On leaving his parents to join his class at Cambridge, he did not leave behind him their good influence, which was blended with all his thoughts and feelings, and kept alive by an affectionate and frank correspondence with his father. He found, too, at the University a never-failing supply of good counsel from the friendship of his cousin, the Rev. Dr. Clarke of Boston, who took a deep interest in his welfare, and was honored by him as his "oracle." He found also in his teachers and guides — in Willard, Tappan, Pearson, Webber, and their associates — men of piety as well as learning, whose whole example and influence pointed to heaven, and led the way.

These were distinguished advantages, but not more distinguished than were his fidelity and wisdom in the improvement of them. Dr. Clarke introduces those beautiful "Letters to a Student in the University of Cambridge," which were addressed to him, by alluding to other peculiar advantages. "Your superior qualifications," he says, "for admission into the University give you singular ad-

vantages for the prosecution of your studies." "Happy for you, they who superintended your education were less anxious that you should be early fitted than that you should be well fitted for the University. You were, therefore, indulged with a year extraordinary in preparatory studies." "Thus informed, you begin the college life with every advantage. You have anticipated the academical studies, and, if you persevere, your future improvements must be answerable to your present acquisitions. Four important years are now before you."

Important years indeed, — for good or for evil! To John Pickering they were full-fraught with good. To some others they have proved calamitous. How is this to be accounted for? Here, Gentlemen, is a problem worthy of your Christian philanthropy, and your most profound philosophical wisdom. What problem in the material world has stronger claims on your attention, as men of science and learning, pledged to advance the best interests of humanity? Since the institution of your Academy, many of its expressed objects of scientific inquiry have been successively assumed by other associations specially devoted to them. Why, then, may you not give attention to some of your implied duties, and pursue inquiries in the intellectual and moral world, — inquiries alike practical and philosophical, and more immediately connected with the loftiest object of your institution, — the advancement of the honor, dignity, and happiness of a free people? Might not the laws of man's moral nature be more clearly understood? Might not the knowledge of them be made more effectual for the attainment of his best education? Such inquiries would seem particularly appropriate to the American Academy, which was originally designed to be subservient to the great objects of our venerable University.

I pray you, Gentlemen, to pardon this suggestion, and accept it

as my apology, if I should appear to pay a disproportioned attention to Mr. Pickering's academical life.

His advantages, upon entering the University, were certainly great, and in some respects peculiar. But they did not consist in his extraordinary intellectual acquirements, or his fine natural powers, or in both together, so much as in his complete moral and religious training, his cherished love of learning, his correct habits, his filial piety, which made the wishes of his parents and uncle his own, and that wisdom, so rare in youth, which led him to follow experienced guides rather than prejudiced companions, and not only to shun all noxious habits, but, like his prototype, Sir William Jones, to avail himself of every "opportunity of improving his intellectual faculties, or of acquiring esteemed accomplishments." Such as these were his preëminent advantages. Some of those students who have most signally failed in their collegiate course were, like him, distinguished for their mental powers and preparatory acquirements, wanting only his moral strength and his wisdom. How it might have been with him, had his mother, instead of her gentle religious nurture, given him lessons of frivolity and fashion, and had his father and his uncle been as observable for their selfish indulgences as they were remarkable for their public and private virtues and their exalted Christian character, and had his teachers, moreover, instilled into him the poison of an irreligious example, we can only conjecture. So, too, we can only conjecture what sort of a character King George the Fourth might have become, had he received the nurture and education which blessed the youth of John Pickering. But while we believe that the laws of the moral universe are as fixed in their operation as those of the material world, we cannot doubt that the result, in either case, would have been essentially the reverse of what it was.

Mr. Pickering entered the University at a juncture when all his strength of principle and all his wisdom were needed to guide him through the trying scenes that awaited him. The tempests of excitement and disorder swept over his class, in their Sophomore year, prostrating numbers of them apparently as strong as himself. Expulsion, rustication, suspension, all followed in rapid succession, for offences to which nothing could have prompted the student but those maddening stimulants, the plague of which no one then knew how to stay. Pickering's virtuous sensibility was outraged by the terrific ravages of this moral plague, as he manifested at the time by a characteristic expression of his abhorrence, — quoting those emphatic lines of Virgil: —

> "Non, mihi si linguæ centum sint oraque centum,
> Ferrea vox, omnes scelerum comprendere formas
> . . . . possim."

It was at this period that the late Judge Lowell, then one of the corporate body of the University, declared the exalted sentiment, that, rather than endure such evils among the students, he would send them off till he had made college a perfect chasm, and then start anew on the right ground.

Pickering's moral indignation, however, bore no unkindness to his offending fellow-students. His heart teemed with sentiments of candor, generosity, and true honor. Nothing of the ascetic or recluse appeared in his disposition or manners. He mingled freely with his classmates in their pleasures and sports, their "jests and youthful jollities," insisting only, that, so far as he was concerned, they should be innocent and proper. And this was a condition exacted by his very nature, unconsciously as it were to himself. His simplicity and singleness of heart were as remarkable as his purity and elevation of mind. He joined the various social as well

as literary clubs, even the gayest of them, the more readily, doubtless, from the very cause which might have restrained others, — a natural diffidence, which he felt it his duty to overcome. The musical club, or Sodality, was best suited to his taste, and afforded him the highest gratification. He cultivated music with delight, both as an art and as a science, and was distinguished in college for his performance on the flute and the violin, as well as for his skill in vocal harmony. As president of the Sodality, he introduced an improved style of music in their performances. Social music became his favorite diversion, affording him through life a lively enjoyment and recreation.

In the whole course of his studies, he manifested a genuine independence and a wise foresight, as well as an energetic industry. Upon his entrance into college, he was surprised to find in what low estimation classical learning was held by the students. Scarcely one among them could be found to do it reverence. The times, however, were very peculiar. The innovating spirit of the French Revolution was raging in the world, and ancient learning, least of all, could expect to escape its baleful influence.

But no example or influence could tempt Mr. Pickering to forsake his first love. He faltered not for a moment in his devotion to a liberal pursuit of classical studies, thoroughly mastering those embraced by his stated exercises, and extending his knowledge much farther both of ancient languages and the literature contained in them. In all his voluntary studies he loved to have friendly companions, and his literary attractions failed not to draw them to him. One of my respected classmates, a learned scholar and divine of this city, who sympathized with Mr. Pickering in all his philological researches, has told me of the delightful hours they passed together at Cambridge in reading various classic authors;

and he remembers another classmate as having been attracted to join them, now as distinguished at the American bar as he then was in college. He remembers, also, the gratification with which they welcomed the addition to their number of a fine classical scholar from England, who entered Mr. Pickering's class at an advanced period, and most heartily sustained him in his favorite studies. I take pleasure in alluding to these bright examples, as being illustrative not only of Mr. Pickering's character and influence, but also of the tendency of classical learning itself to produce such examples.

These favorite studies, however, were not allowed to occupy more than their due proportion of Mr. Pickering's time in college. The mathematics and natural philosophy were studied by him with scarcely less ardor, and with equal success; nor was any branch of learning overlooked by him, which he had an opportunity to cultivate. Academic honors had no influence in shaping his plans of study or his rules of conduct. So far from this, he dreaded them, as an unwelcome visitation, if they required his speaking before the public. He pursued knowledge for its intrinsic value and because he loved it; and conducted himself nobly by following out his inbred sense of propriety and Christian duty.

His father, being a member of President Washington's administration, was too much engaged by his public duties to do more for his son's improvement in college than by occasionally writing to him. Such a father, however, could not fail to do much in this way, and to exert a powerful influence upon such a son. Their correspondence, were it open to us, would afford the best illustration of Mr. Pickering's condition and circumstances in college, as well as of the motives which governed him, and the manliness and moral beauty of his youthful character. An intimate college companion remembers some of the father's letters, and the excellent

instructions they contained. It is to be hoped, that, at some day, they may be permitted to see the light.

Mr. Pickering enjoyed his college life in a high degree, and justly appreciated its privileges; yet he felt the want of an instructer in elocution, and, unlike some students of that day, he lamented the inability of the professor who taught English composition to attend to his class in that exercise, which he considered among the most important in college. By such disadvantages he was stimulated to greater diligence in supplying himself with instruction. In the practice of speaking he found much aid from an ancient secret society, composed of select members from the two middle classes, called the Speaking Club, then in high esteem; the members of which held regular meetings for declamation and mutual improvement, and were alike faithful and kind in pointing out each other's faults of elocution, sometimes entering into discussions which served to accustom them to extemporaneous speaking. At that period, also, the resident members of the Phi Beta Kappa Society, during the Senior year, were a working society for mutual improvement in composition, reasoning, and elocution. They had frequent meetings within the walls of college, at which the members, in turn, produced and read dissertations or forensic arguments, which, with occasional colloquial discussions, were found highly useful. Mr. Pickering could not fail to make them so to himself. His leisure hours, too, whether given to social intercourse and recreation, or to classical and other well-chosen reading, were fraught with improvement of much value. His learned friend, Dr. Clarke, was ever ready not only to advise him as to the course of his reading, but to lend him the best books for his purpose.

In his knowledge of the French language he had greatly the advantage of most of his classmates. His chief object at college in

respect to this was to acquire a correct pronunciation of the language, in which he was remarkably successful, his instructer being a native of France, and particularly pleased to give him the attention which he desired. He had, indeed, a peculiar facility, in all the foreign tongues which he studied, in acquiring ease and correctness of pronunciation. His delicately tuned ear was in this an excellent guide. Thorough and complete knowledge was sought by him in all his studies. Hence he accustomed himself to the practice of writing in the principal languages he acquired, — a practice which he commenced at college in the French, and continued afterwards in the Portuguese, Italian, Latin, Greek, and some other tongues. No intellectual labor was irksome to him which looked to the increase or improvement of his knowledge.

Though Mr. Pickering had no thought of ever becoming a medical student, yet, in pursuance of the principle to avail himself of all opportunities of acquiring valuable information, he attended, in his Senior year, Dr. Warren's lectures on anatomy, and Dr. Dexter's on chemistry. With the former he was greatly delighted, as affording him both instruction and entertainment in a high degree. The latter, from the nature of the subject, were far less interesting; yet he was stimulated by them to unite with several of his classmates in pursuing the study by themselves, making such experiments as with their small apparatus were in their power.

The peculiar delicacy of Mr. Pickering's mind and feelings exposed him, in early life, to no little suffering from diffidence, which it required all his resolution and sense of duty to overcome, and which, perhaps, he never entirely subdued. Yet few ever exceeded him in dignity of mind, strength of character, and firm, uncompromising principle. From his modest reluctance to speak in public, he would have gladly avoided his first college honor, a part in

an English dialogue, at an exhibition in his Junior year; but his resolution enabled him to perform it to the gratification of his friends, as it did also his second part, a finely written Latin oration on Classical Learning, a subject suggested to him by his ever-attentive friend, Dr. Clarke. Great as was his enthusiasm for classical learning, he had, in college, as real a love for the study of the mathematics, and highly distinguished himself in this department. Near the close of his Senior year, he received the honor of a mathematical part, which appeared to give him more pleasure than all his other college honors. It afforded him an opportunity to manifest his profound scholarship in a manner most agreeable to his feelings. When he had delivered to the Corporation and Overseers this part, containing solutions of problems by fluxions, he had the rare satisfaction to be told that one of them was more elegant than the solution of the great Simpson, who wrote a treatise on fluxions, in which the same problem was solved by him. Such was the distinguished honor that crowned Mr. Pickering's intellectual labors in college.

At his Commencement, he had assigned to him a new part, one never before introduced, which, with the subject, was intended by the government as a particular honor to him, and his classical friend before mentioned, from England. This was an English colloquy, and the subject given them was, "A Panegyric on Classic Literature." The execution of the part was honorable to both, and formed a suitable close to Mr. Pickering's academical life.

At this important era, which fixed the character of his whole earthly career, we may be allowed to pause for a moment to contemplate his attainments and his example. His education, in all its essential objects, was now complete. Together with the acquisition of a rich fund of various learning, all his faculties were

so disciplined and improved, his love of knowledge so inflamed, and his ambition so exalted, that he could not fail to extend his views, and urge his pursuit of learning with increased energy. Alike powerful in mind and pure in heart, amiable, intelligent, and armed with all the strength of virtue and religious principle, he was prepared to enter the world of action, temptation, and trial. He at once inspired respect, together with the most entire confidence, wherever he became known, in the stability of his principles. They who intimately knew him would as soon have thought that one of the planets would shoot from its orbit, as that he would depart from his honorable course.

Whether, as many of his classmates affirmed, he bore from the University the reputation of being the first scholar of his class, it is of little consequence to inquire; nor is it material to measure very exactly the magnitude or extent of his talents; it is enough to know that they were not so great as to raise him above the strictest virtue, or the least of moral obligations, and that in accomplishing his education he made himself a model scholar, and laid the foundation of his eminent distinction and usefulness in life. To profit from his example, we must learn how he attained to such excellence. For this purpose it is that we have traced so carefully the progress of his education, and considered his advantages and disadvantages, and the manner in which he improved them; for he appears to have improved both, or rather to have made what were regarded as disadvantages the means of greater improvement. Though he regretted that more complete instruction was not afforded in some departments of education, yet it was doubtless better for him, with his enlightened industry and wise disposition of his time, to have too few than too many teachers, and to enjoy undisturbed the best hours of the day for study, than to pass through

the most skilful process of recitation. The professors and tutors, whom it was his good fortune to have through college, were able teachers and admirable guides; and, if they taught not all things, they misled in nothing. Had it been otherwise with them, it might have been otherwise with him; for who can be safe, when guides mislead? Mere defect of instruction he could supply for himself, better perhaps than others, with some additional advantages from the spontaneous and independent exertion of his faculties. His fidelity in attending to his stated exercises and observing all the proprieties of a conduct at once courteous, manly, and upright, was not more extraordinary than his industry and sagacity in employing his leisure time to extend his classical and philosophical learning, and to acquire the most valuable accomplishments. Even his hours of convivial recreation were subservient to the growth of his social and generous virtues, and his favorite pleasure consisted in the cultivation and practice of one of the most delightful of the fine arts.

Of all whom I have ever known, from our own or any other University, no one appears better entitled than Mr. Pickering to be regarded as the MODEL SCHOLAR. In saying this, I pronounce his highest eulogium, and present his strongest claim upon the public gratitude. Vast and comprehensive as was his matured learning, and valuable as were its fruits to his country and the world, the finished model he has left for guiding the studies and forming the character of the scholar and the man is infinitely more precious. Any student, commonly well endowed, who has a soul capable of aspiring to excellence, — and what young man, devoting himself to a liberal education, is destitute of such a soul? — may find in this model an unerring guide to the attainment of his lofty object. Faithfully following his guide, he cannot fail of success. One con-

dition only is indispensable, — a condition, too, altogether in his own favor. He must begin and persevere in the spirit of his model. He must abjure every indulgence which has the least tendency to impair his moral or his mental energies, or to induce any injurious or unseemly habit. "*Procul, O procul!*" must be the earnest exclamation of his heart against every form and aspect of moral evil. Thus persevering, he will find his progress as delightful as his success is certain.

The instructer, equally with the student, may gain wisdom from the contemplation of such a model, — the model of a character which it is his peculiar province to form. The faithful ship-builder spares no pains in studying the best model of his art, and making his work strong and complete. Much more will the faithful builder of a human character, freighted with treasures of immortal value, seek the highest degree of perfection in his work. Here, in this noblest of human works, the "wise master-builder" is deserving of all honor. He entitles himself preëminently to the gratitude of mankind.

I trust, Gentlemen, you will not regard these remarks, intended as they are to elucidate Mr. Pickering's distinguishing merits, as an impertinent digression, or charge me with a waste of your time in dwelling so long upon that portion of his life which is sometimes passed by with a single glance. It is more pleasing, I know, to admire the ripened fruit than to watch the culture of the vine or the tree which bears it; but the latter is quite as useful an employment as the former. Having witnessed the planting of a noble tree, and carefully observed its early culture, its growth and expansion, its full foliage and fair blossoms, we may not only admire its fruit, but understand the means by which it is produced.

A smiling Providence appears to have guided Mr. Pickering at

every step of his progress. Upon leaving the University and returning to his parents in Philadelphia, he found himself in the very situation which, of all others, he must have preferred for his continued advancement in various excellence. His father, then Secretary of State, introduced him at once into the most intellectual and cultivated society, and afforded every desirable opportunity for the gratification of his literary taste and ambition. Having chosen the law for his profession, he entered the office of Edward Tilghman, Esq., and closely pursued his legal studies for about nine months, when he was appointed secretary of legation to William Smith, who had been a distinguished member of Congress from South Carolina, and was then to be our minister at the court of Lisbon. Nothing could have been more agreeable to Mr. Pickering than such an appointment. It opened a delightful prospect for the indulgence of his curiosity in seeing Europe, and for the extension of his literary and philosophical researches. In Mr. Smith, who was as remarkable for his amiable disposition as for his talents, he was sure to find a most valuable friend and companion.

During his short residence in Philadelphia, he generally devoted his early morning hours, as well as his evenings, to classical reading. He assured a friend, whom he had left a student at Cambridge, and whom he wished to imbue with a genuine love of ancient learning, that, instead of seeing the inutility of the classics, as many of his classmates had predicted he would, he was fully convinced of their value, and was then pursuing them, particularly Greek, with more ardor than ever. His ardor in the pursuit and promotion of Greek literature, as we all know, never abated.

In August, 1797, Mr. Pickering, after a voyage of twenty-seven days, arrived at Lisbon. On the passage he studied the Portuguese language, so that, by taking a few lessons after his arrival,

he was able to speak it with tolerable ease. Most of his time in Portugal was passed at Lisbon, except during the hot months of summer, when Mr. Smith resided at Cintra, a beautiful rural retreat, much resorted to by the wealthy inhabitants of Lisbon. Here Mr. Pickering, little inclined to mingle in the fashionable amusements going on around him, had leisure for his own pursuits, and found constant enjoyment among the orange and lemon groves abounding there, and from the mountainous, romantic scenery of the place. He used to speak of some other excursions from Lisbon. He visited the famous monastery of Batalha, a grand specimen of elaborate antique architecture, which made a deep impression upon his mind, and he often spoke of it afterwards with enthusiastic admiration. He also visited the ancient University of Coimbra, where the venerable professors paid him the kindest attentions, and at parting embraced him as a friend. He had, indeed, always a language of the intellect, heart, and manner, alike intelligible and pleasing to all, which at once secured him friends wherever he went.

He travelled little to see the country. Much as he loved nature, he loved humanity more. Whatever related to the human mind, or to human society, in any state or form of its existence, — institutions, laws, manners, arts, education, language, — engaged his deep attention. In pursuing his studies at Lisbon, he felt at first the want of books; but making friends, in his wonted manner, of some learned monks, whom he visited in an old convent, he obtained through their kindness those which he most needed. The civil law and the law of nations, with the study of languages, were the leading objects of his attention. He read Vattel's *Law of Nations*, in the original French, and entered upon Justinian's *Institutes*. Meeting with a learned native of Damascus, where the

Arabic language was spoken in its greatest purity, he studied that language; and, at the same time, made it the occasion of acquiring a more familiar knowledge of the literature and affairs of Portugal, by conversations on these subjects with his friendly instructer, who had lived many years in the country. He also studied the Italian language at this time, and probably the Spanish. It having been expected that Mr. Smith would be sent on a mission to Constantinople, Mr. Pickering indulged the pleasing vision of seeing the East, and treading the classic ground of Greece and Rome. With this view, he undertook the study of the Turkish language; but the mission to that country was abandoned, and he never realized his anticipated delight.

In Lisbon, as in college, music was his favorite social recreation. Mr. Smith himself had a fine taste for music, and the musical parties among his friends were to Mr. Pickering a source of instruction as well as entertainment. He joined them on the flute, and thus acquired that correct taste and cultivation which he could hardly have obtained at that time in his own country. He became so well versed in the science of music, that in later life he took much pleasure in explaining its principles to his young friends. His mechanical ingenuity, which discovered itself so early in life, was perhaps most manifested in his practical knowledge of the construction of musical instruments.

The noble father kept a steady eye upon his son's higher improvement, and therefore, satisfactory as was his connection with Mr. Smith, he made arrangements for his removal to London, where his advantages would be more ample. During the two years he had passed with Mr. Smith, their mutual regard had ripened into the sincerest friendship, and, on parting with him, Mr. Smith expressed his exalted esteem, and his deep regret at losing the society of so estimable a companion and friend.

Under the continued smiles of Providence, Mr. Pickering found himself, in November, 1799, happily situated in the family of Rufus King, our minister at the court of St. James, surrounded by the most desirable means of intellectual progress and rational enjoyment. He was honored by an intimate reception in the family of Christopher Gore, then at London, residing in Mr. King's immediate vicinity. He gained the warm friendship of both these eminent gentlemen, and met in their respective families the best society, whether for his taste or his manners. His social pleasures at this time were of a high order, and rendered altogether delightful by the simultaneous arrival in London of a classmate of kindred sentiment and taste, who afforded him all that exquisite enjoyment of confidential intercourse which springs from college friendship.* This beloved friend survives to honor his memory and bear witness to his worth. He had access to his inmost thoughts and feelings, and can put the seal of truth to the strongest lines of excellence which I have drawn. I have only to regret that his skilful and delicate pencil was not employed to paint the picture.

Our consul at London was Samuel Williams, Mr. Pickering's friend and cousin, who freely offered to advance whatever funds he might desire for the purchase of books. His father having encouraged him to indulge his inclination in such an expenditure, he availed himself largely of Mr. Williams's kind offer, and selected and brought home with him an extensive and choice library, which in the end became a rich acquisition to the literature of New England.

Mr. Pickering was the private secretary of Mr. King, and also the instructer of his sons in their vacations from school; but he found much time for his literary pursuits. These were such as we

* Dr. James Jackson.

should naturally suppose, from his taste and settled habits of study; and his proficiency was in proportion to the excellence of his habits and his disciplined powers of mind. His ardent curiosity and love of knowledge, his keen, philosophical observation, his clear perception, sound, discriminating judgment, and close, penetrating attention, with his strong and exact memory, all improved by constant exercise, and aided by a judicious observance of order and method, will go far to account for his acquirements at this period, as well as for the vast accession afterwards made to his learning and intellectual ability. Together with his unremitting industry, he possessed the mighty power of concentrating his whole attention upon the object before him, and pursuing it with intense application. This he acquired the habit of doing, like his illustrious friend Bowditch, in the midst of his family, without being disturbed by conversation carried on around him, or even diverted by music, which he so loved; yet cheerfully submitting to necessary interruptions, and instantly returning again to his laborious mental work.

All his spare time, after fulfilling his duties to Mr. King and to society, was devoted to the various juridical and philological studies which he pursued in so systematic and thorough a manner. Taylor's *Elements of the Civil Law* he completely mastered, making it a point to read entirely through the various recondite Greek quotations with which the work abounds, — an entertainment, we venture to say, never before indulged in by any American lawyer. In connection with this, he read parts of Livy relating to the Roman law and constitution, investigating any matters of difference between these authors. He, of course, kept up his intimacy with the classic writers of Greece and Rome, and read various learned works connected with them, among the most considerable of which

was Havercamp's *Sylloge Scriptorum de Linguæ Græcæ Pronuntiatione.* He generally took up first in the morning some ancient author, most frequently Cicero, delighting at such moments to read a portion of his ethical or philosophical writings. His practice now, as in college, was to pursue different studies each day, mingling with the severer the more lively. Along with Taylor, which he made a severe study, he read through Dryden's prose works, which, with his philological taste and views, were highly entertaining. With Euclid's Geometry, Locke's Human Understanding, and the philological works of Harris and Murray, he read a copious history of the French Revolution, and several works of Edmund Burke on the same eventful subject, — an author with whom he was greatly delighted on all subjects, and of whose genius and sagacity he appeared through life to feel an increasing admiration.

As Mr. King passed the summer seasons at Mill-hill, a fine rural situation about five miles from London, Mr. Pickering availed himself of the opportunity it afforded for the study of botany, and with the aid of Professor Martyn's lectures he acquired a competent knowledge of that beautiful science, which became a source of refined gratification to him, and never more so than when he had the pleasure to impart it in his own family.

But Mr. Pickering was not so devoted to his studies as to overlook any important means of information. He occasionally attended the meetings of Parliament and the courts of law, especially the Admiralty Court, where Sir William Scott was the judge, in the proceedings of which he was particularly interested, from its connection with the law of nations, and from its having before it various American cases. Though the theatre, in its ordinary performances, had no attractions for him, yet he went to hear Kemble

and Mrs. Siddons, and was deeply impressed by the transcendent powers of the latter. In all his attendance on English speaking, whether in the Parliament, the courts, or the theatre, he was a strict observer of the use and pronunciation of the language, and had already begun to note peculiarities of expression, with a view to ascertain how far the true English tongue was corrupted in America.

Mr. Pickering's incessant occupations prevented his journeying much in England. He failed not, however, to visit Oxford, where he could find so much to gratify his highest curiosity. His classical and mathematical scholarship, but for his modesty, might have made him feel more at home either at Oxford or Cambridge than anywhere else in England.

Fortunately, he had an opportunity to visit the Continent before his return to America. In the winter and spring of 1801, he passed three or four months in travelling through France and the Netherlands. In Paris, he was introduced to Madame de Staël, the object of attraction to the literati and politicians of the day. He saw Bonaparte at the height of his renown, with Italy at his feet, whose noblest works of art he had transported to France. As a lover of the fine arts, Mr. Pickering could almost visit Rome in Paris. At Leyden, he became acquainted with the celebrated Luzac, Greek professor in the University, who afterwards honored him with his correspondence. In Amsterdam, he gained the friendship of Dr. Ballhorn, who soon after published a learned juridical work, dedicated "Viro clarissimo Joanni Pickering." To a youthful scholar such testimonials of merit must have been as gratifying as they were honorable.

Soon after Mr. Pickering's return from the Continent, he set his face homewards. The extensive library, before alluded to, was

collected by him with great care, partly in Portugal and partly during his travels in France and Holland, but principally among the booksellers of London, through whom he found access to some of the rarest treasures both of ancient and modern learning. This library was no unworthy representative of the treasures stored in his mind. He had been as wise and faithful in the use of books, as he was skilful in the selection of them. No one better knew the true value and purpose of books, or made them more effectually the means of practical wisdom and goodness. Not the slightest tinge of pedantry ever appeared in his conversation or manner.

> "Ingenuas didicisse fideliter artes
> Emollit mores, nec sinit esse feros."

Mr. Pickering studied literature and the fine arts both with fidelity and delight. Not only music, but poetry, painting, architecture, and especially sculpture, gave him pleasure as lively as it was refined. The influence of these favorite pursuits appeared in his disposition, affections, and whole conduct, and, together with the effect of the best society, gave a peculiar charm to his manners; which were so simple as not to arrest observation, and yet so refined as to bear the closest scrutiny, and which, having their foundation in his good heart, and being guided by the nicest discrimination as well as true delicacy of feeling, were sure to recommend him to the favorable regard of all, and to the cordial respect of the most worthy.

We might abundantly show the high estimation in which Mr. Pickering's character and talents were held by his eminent friends, Rufus King and William Smith, were their correspondence with his father at our disposal. But for this we must wait till the long hoped-for biography of this pure, ardent, and able patriot and

statesman is given to the world; — a service of filial piety, which it was in the heart of our lamented friend to render, but which now, alas! must be performed by another.

In November, 1801, Mr. Pickering, with his noble library, after a stormy and perilous voyage of forty-five days, arrived in Boston. Few scholars ever had a more brilliant return from abroad, or a warmer welcome home. One disappointment, however, awaited him on his arrival; — he did not meet his revered father, who was far away in the interior of Pennsylvania, out of office, enjoying the purest reward of laborious patriotism, — the veneration of his country and — *an honorable poverty*. This led to another disappointment. Mr. Pickering, in the purchase of his precious library, relying upon his father's advice and resources, had incurred a debt, which he had now no means of discharging but from the library itself. To part with any portion of this cost him a struggle, but the moment he saw it to be his duty the struggle was over. He sold more than two thousand volumes by public auction, under such favorable auspices as enabled him to cancel his debt, and to retain the residue of his books, to him probably the most valuable part.

Thus a smiling Providence returned, but not to him only; the friends of learning shared it with him. The distribution of such a collection of books, together with his own bright example, gave an important impulse to the pursuit of ancient learning. The classic Buckminster soon after imported, on his return from Europe, a similar collection, which, at his deplored death, were in like manner dispersed through our literary community. The germ of the Boston Athenæum, too, may, doubtless, be traced to the sale of Mr. Pickering's library and the effective impulse which it sent abroad.

Colonel Pickering, ever watchful to secure for his son the highest

advantages, had made some arrangements for the completion of his law studies with the late eminent Theophilus Parsons, influenced partly, perhaps, by an old family friendship, — Mr. Parsons having been named for the Colonel's uncle, the Rev. Theophilus Pickering, and been consequently a welcome guest in his father's family. But the earnest wishes of the good uncle, whose unvarying affection had followed Mr. Pickering from infancy, prevailed with him to return to Salem, where he entered the office of Mr. Putnam, afterwards a judge of the Supreme Judicial Court.

Here, attracted by Mr. Pickering's well known character, I joined him, to finish my own professional studies. While he had been abroad, expanding his views of men as well as books, I had been confined to a didactic sphere within the walls of college. On emerging into the world, nothing could have been more welcome to me than such a companion. His society was alike instructive and delightful. It brightened the whole time I was with him, and made it one of the sunniest spots of my life. From that moment, I was for many years a close observer of him in public and in private, at the bar and among his friends, in his walks and amid his studies, in the bosom of his family and at my own fireside, and to my view his whole path of life was luminous with truth and goodness, — never obscured, no, not for a moment, by the slightest shade of obliquity in him. I cannot withhold this cordial testimony. To the eye of reflecting age, truth and goodness are every thing, mere genius and fame nothing, — in the comparison, absolutely nothing.

It was while we were thus together in Mr. Putnam's office, that Mr. Pickering revised an edition of Sallust; an edition pronounced by an able critic in *The Monthly Anthology* to be "in every respect preferable to the Dauphin Sallust," and "not unworthy of the classical reputation of the reputed editor."

Justly to appreciate this literary labor (if labor that may be called which was a pleasant recreation), it is necessary to understand the circumstances under which it was performed. Certain booksellers in Salem, having determined to publish a reprint of Sallust, asked of Mr. Pickering the favor to correct the proof-sheets, which he was unwilling to grant without making it the occasion of some valuable improvement. Hence the revised edition. President Willard, of Harvard University, was consulted about it, as the college government had recently made this author a preparatory study for admission, and his suggestions were followed in the undertaking, — an undertaking wholly gratuitous, and pursued rather as an amusement than as a work of elaborate care. It was, indeed, an interesting as well as liberal amusement, and I could not participate in it without receiving a strong impression of Mr. Pickering's classical taste and knowledge. Nearly the whole of this edition was destroyed by fire, before it had an opportunity to be tested by public opinion.

As evidence of Mr. Pickering's undiminished ardor in the pursuit of Greek literature, it deserves mention, that, when he was thus dividing his time at the office between Sallust and the law, he was employing a portion of his hours at home in reading an old edition of Homer with the scholia of Didymus. It appears to have been his practice through life thus industriously to mingle literary occupation with his domestic enjoyments.

In March, 1804, Mr. Pickering was admitted to the bar, and commenced the practice of law in Salem. On the third day of March, 1805, he was married to his second cousin, Sarah White, and in the following May they became members of the First Church in Salem, then under the pastoral care of the Rev. Dr. Prince, of which Mr. Pickering was made one of the ruling elders.

This continued to be his place of worship while he remained in his native town, and also when he afterwards returned to it for his summer's residence. But on his removal to Boston, in 1827, he with his family attended public worship in an Episcopal church. He was truly liberal and generous, yielding in matters of opinion, as in other things, more than he claimed; for, with the Apostle, he attached less importance to particular tenets, than to "love, joy, peace, gentleness, goodness, faith." In all his relations, civil and religious, he was alike useful and exemplary, honored and beloved.

Though never inclined to a political life, Mr. Pickering sometimes acceded to the wishes of his friends so far as to partake in the administration of public affairs within our Commonwealth. For several years during the late war with England, he was a representative from Salem in the General Court, and after the war, for some years a senator from the county of Essex, then again from Suffolk, and once a member of the Executive Council. He was very early, as you know, elected a Fellow of the American Academy, and afterwards a member of the American Philosophical Society, and of various other learned bodies at home and abroad.* He also received the highest academic honors from more than one university. But political and exterior honors appear of little importance in connection with his intellectual career. His true distinction springs directly from his intrinsic excellence.

In following Mr. Pickering through his education, and during his residence abroad, — which was but an extension of it, — we have traced his progress more minutely than is necessary in pointing out the results of his education and learning. It is not so important that we should have a complete view of his labors and literary productions, as that we should clearly understand the spirit and the

* Note A.

principles which actuated him in accomplishing them. Few may expect to enter into his labors, or to attain to his distinction; nor is that material; but all, of whatever profession or employment, may imbibe his generous spirit and act from his exalted principles, and this is the essential thing.

His first publication, after his admission to the bar, was an oration delivered in Salem, on the fourth of July, 1804, which was received by his political friends with distinguished marks of favor, and published at their desire. Its sound and philosophical views of government, and its able exposition of public affairs, and the spirit and progress of parties in the United States, with its clear, appropriate, and manly style, give it a permanent value, and render it particularly interesting, as one of Mr. Pickering's earliest productions.

We are reminded by this oration of the opinion, which Mr. Smith was known to express in Lisbon, that Mr. Pickering's abilities remarkably fitted him for a diplomatic career; an opinion which became more manifestly just, as he advanced in the improvement of his abilities and the acquisition of general learning. His knowledge of jurisprudence, with his various literary and scientific attainments, eminently qualified him for any station in the government at home or abroad. And had the spirit of Washington continued to preside over the destinies of the country, such men as Mr. Pickering would have continued to be preferred for high political trusts. But, I think, we cannot doubt that our honored friend, both by nature and education, belonged to learning, and not to politics, or even to the law, distinguished as he was in the science of jurisprudence.

"Spirits are not finely touched,
But to fine issues."

Providence, in bestowing his rare philosophical and literary abilities, destined him for the purest intellectual pursuits. Spirits far less "finely touched" might, for that very reason, better succeed in the ordinary conflicts of the forum; conflicts, in which fine powers and finer feelings, like his, must be quite out of place. Instruments of exquisite metal and polish are not suited to work upon rude and rough materials.

When, therefore, upon the resignation of Dr. Eliphalet Pearson, Mr. Pickering was appointed, in June, 1806, Hancock Professor of Hebrew and other Oriental Languages in Harvard College, many of his friends, as well as friends of the University, were very desirous that he should accept the office, regarding it as a sphere in which his extraordinary learning and accomplishments would be most productive of benefit to the country and of honor to himself. The late Dr. Bowditch, was, at the same moment, appointed to succeed President Webber as Hollis Professor of Mathematics and Natural Philosophy. A remarkable coincidence! These eminent men, near neighbours and intimate friends, were doubtless better qualified for the offices to which they were respectively appointed than any other two individuals in the whole country. They were also admirably suited to coöperate in giving a spring to the University in all excellence, intellectual and moral. Both were liberal, elevated, and disinterested in their views of education and learning; both had an insatiable thirst for knowledge, and a supreme love of truth and goodness; the one was devoted to science, the other chiefly to literature; both were exalted and spotless in reputation, alike raised above all suspicion of moral failing, yet with some striking points of contrast; the one, quick and ardent, would leap to a logical conclusion at a single step; while the other, cautious and patient, like Lord Eldon, could never weigh

his arguments or consider his subject too deliberately. "*Suaviter in modo, fortiter in re,*" was applicable to both; but the one could put aside his gentleness of manner when he felt it to be his duty; the other could hardly be brought to feel it a duty. Both were as exemplary in Christian virtue, in the exercise of social benevolence and the domestic affections, and in purity of habits, as they were distinguished in literature and science; and both would have discountenanced by their powerful example those indulgences and practices which often lead the young student into habits more injurious to him than any amount of learning can be beneficial. But both, to the deep regret of the University, declined their appointments.

Seven or eight years later, on the establishment of the Eliot Professorship of Greek Literature, Mr. Pickering was still more urgently pressed to be a candidate for the new professor's chair. A friend to him and to the University was authorized, by the President of Harvard College, to ascertain "whether any and what definite amount of compensation would induce him to accede to the proposition." But Mr. Pickering gave no encouragement for proceeding to his election. The literary duties, no doubt, were attractive, but the disciplinary cares connected with them had a forbidding aspect. Some of his friends, moreover, very naturally desired for him a sphere of usefulness which appeared to them more eminent and extensive. Nor were they too sanguine in their views of his future eminence. Yet who could now say that he might not have been still more extensively useful, had the direct influence of his superior powers and virtues, his teachings and his example, been exerted upon the numerous young men since educated at the University, and been diffused through them over our whole country?

Mr. Pickering was a grateful and devoted son of the University, which so justly appreciated his merits, and which, at a subsequent period, bestowed upon him its highest honors. For many years he was an efficient member of the Board of Overseers, always ready to exert his influence to advance the usefulness and reputation of his Alma Mater. His last admirable report, as one of the visiting committee, in 1840, embodies views and principles of university education which ought never to be overlooked or forgotten.*

We need not dwell here upon his learning as a jurist, or upon his excellent qualities as a practising lawyer. These have been portrayed and exhibited on an occasion before referred to, in the best manner for extending their influence in the profession of which he was so bright an ornament. We should remember, however, that, while pursuing his extensive literary researches, and performing numberless intellectual labors for the public and for individuals, he was incessantly engaged, to the last year of his life, in the arduous duties of his profession, — duties which not unfrequently imposed upon him a drudgery as irksome as it was laborious. He felt the full weight of it, and but for those interesting questions which led him to examine principles, his profession, as he sometimes remarked, would have been nothing but labor and drudgery. Having ascended to the fountain-head of jurisprudence, and stored his mind with great principles, he took delight in tracing these in their practical application. In this view, he regarded his profession as a most honorable one. The friends of humanity and learning, however, will not cease to regret that the "labor and drudgery," which others might have well performed, should have taken so

* Note B.

much of his precious time from those noble intellectual pursuits for which he was so peculiarly competent. Especially must they regret, that, on removing to the metropolis, where his powerful literary influence was so important, he should have felt it necessary to present himself only in his professional character. The office of city solicitor, which he held for a great number of years, brought with it much additional labor, though occasionally relieved by the occurrence of those interesting questions which he loved to investigate and settle. The numerous legal opinions which he was called upon to give, we are assured, were as remarkable for their soundness as for their learning.*

Mr. Pickering's literary productions and labors, aside from the practice of his profession, were so abundant and multifarious, that it is not possible for us, on this occasion, to take a complete or distinct view of them. We must classify them as well as we can, according to their kindred relation, contenting ourselves with some brief remarks.

First, we class together those writings which partake of a professional character, while they are also made attractive to the general reader. The most considerable of these, perhaps, is the able discussion of "National Rights and State Rights," which was drawn from him by the case of Alexander McLeod, — a case involving a question of the highest public importance, — "*dignus vindice nodus.*" It was, indeed, worthy of his interposition, and his learning and logical ability were equal to its solution. He brought to the discussion such a thorough knowledge of the subject, with such clear views of our federal and state relations, urged with such weight of argument, justice, and truth, that he settled this great

* Note C.

national question upon principles which can never be shaken. For this single service he is entitled to a grateful remembrance so long as any value is attached to the union of the States.

The next of this class, in point of general interest, is the article upon Curtis's *Admiralty Digest*, published in the *American Jurist*, little known, probably, except to lawyers; yet I could not point to any work which contains, within the same compass, more matter of permanent interest to every reader of American history, and which throws more light upon the foreign policy of our government from the time of Washington's declaration of neutrality, in 1793, to the declaration of war, in 1812, under President Madison.

Another dissertation, published in the *Jurist*, entitled "Remarks on the Study of the Civil Law," is highly useful to the classical scholar, and, indeed, to every educated gentleman, though designed more especially for civilians and lawyers. Early impressed with the importance of this study, Mr. Pickering wished to draw the attention of the bar to it as among the most effectual means of raising the dignity and usefulness of the profession. He regarded the civil law as a wonderful repository of human reason, the source of a large portion of our common law, and the basis of that international code which governs us and all the nations that constitute the great community of Europe. At the close, he expresses a strong desire to see this branch of jurisprudence take its proper rank in our law schools, as well as among our practitioners at the bar. Alluding to an illustrious example of professional liberality in the donation made by our late learned countryman, Dr. Dane, to the University of Cambridge, for the advancement of *American* law, he adds: — "We earnestly hope that some benefactor of equal liberality will soon be found who will devote a portion of the well-earned fruits of an honorable life to a chair for the civil law in that ever cherished institution."

As akin to this subject, we may glance at the article, written by Mr. Pickering for the *Encyclopædia Americana*, on the "Agrarian Laws of Rome"; a correct view of which laws he considered indispensable to general readers, as well as lawyers, who would have just notions of the Roman history and constitution. Contrary to the general impression, that those laws were always a direct infringement of the rights of private property, he shows that the original object of them was the distribution of the public lands, and not those of private citizens, though they might sometimes violate private rights; as certain laws of our State legislature, agrarian in principle, made for the relief of illegal settlers on Eastern lands, violated the rights of proprietors of those lands.

The "Lecture on the alleged Uncertainty of the Law," delivered by Mr. Pickering before the Boston Society for the Diffusion of Useful Knowledge, is an excellent production. Instead of seeking for his auditors an hour's diversion by indulging their love of pleasantry at the law's expense, he aims at what is true and useful, and affords both entertainment and instruction. His object was, to promote a just respect for the science of the law by securing for it a proper confidence. The science itself is as certain as the sciences in general; but when we come to apply it to the innumerable objects to be regulated by it, then the same uncertainty takes place, which is experienced in the other sciences, not excepting the mathematics. The various learning and striking illustrations with which this beautiful lecture abounds place it among his most valuable writings.

The article written for the *North American Review*, entitled "Egyptian Jurisprudence," is as characteristic as it is curious. No other American scholar, we think, would have attempted it. For several years, he observes, the learned world had been in

possession of some original and very ancient legal documents from Egypt; yet, though they had not escaped the notice of jurists on the continent of Europe, he had not seen any allusion to them in the juridical journals, either of Great Britain or of this country. One of these extraordinary documents is an Egyptian deed of a piece of land in the city of Thebes, written on the papyrus of that country, more than a century before the Christian era, with the impression of a seal, or stamp, attached to it, and a certificate of registry on its margin, in as regular a manner, Mr. Pickering adds, as the keeper of the registry in the county of Suffolk would certify to a deed of land in the city of Boston at this day. Of this curious document, written in Greek, as was common while Egypt was under the Greek dynasty, a learned and ingenious explanation, together with a *fac-simile* of it, is given by Mr. Pickering. The whole article is exceedingly interesting, and affords a beautiful specimen, not only of his rare learning, but of his philosophical taste and skill in the application of his learning.

Such are the chief, though not all, of Mr. Pickering's writings which have a professional bearing. In the *second* class we include those which partake of a legislative character.

As a member of the legislature of Massachusetts, Mr. Pickering rendered important public services, and made himself conspicuous among the eminent men of the Commonwealth. His elaborate "Report on the Subject of Impressed Seamen, with the Evidence and Documents accompanying it," made to the legislature of 1812, the first year of the late war with England, is a durable monument of his patriotism, as well as of his ability and learning. We cannot justly appreciate this undertaking, without looking back to his position, in the midst of that dreadful war, — most dreadful to all reflecting men, who saw and felt that it bound us to fight the

battles of Bonaparte against the civilized world. When this overwhelming conqueror was on his triumphant march against Russia, our government, at the very moment which seemed to suit his views, declared war against England, the only remaining barrier in his way to universal dominion. The power of the elements over him could not be foreseen. The repeal of the British orders in council, the chief alleged cause of the war, having taken place before its declaration, though not known here till afterwards, left the impressment of American seamen, or rather the claim of a right to take British subjects from the merchant-ships of the United States, the only remaining pretext for prosecuting the war. In relation to this subject, great errors had crept into the public documents, and great delusion existed in the public mind. Mr. Pickering thought that he could in no way render a greater service to his country than by correcting those errors and dissipating that delusion. For this purpose, he introduced, in the House of Representatives, an order "to ascertain the number of the seamen of this Commonwealth impressed or taken by any foreign nation." On him, as chairman of the committee thereupon appointed, chiefly devolved the labor and responsibility of the undertaking. It is sufficient to add, that it was accomplished in a manner alike honorable to himself and satisfactory to the legislature. A great mass of evidence was reported, comprised in more than fifty depositions, taken from the principal merchants and shipmasters of Massachusetts, together with a just account of the previous practice of our government in relation to impressments, and a clear exposition of national law on the subject, all showing conclusively that the further prosecution of the war was as unnecessary as it was disastrous.

We cannot follow Mr. Pickering through his important legisla-

tive labors. It must suffice to observe, that on great occasions, or on subjects involving great principles or momentous consequences, his learning and his pen were always in demand, and never withheld. The contemplated separation of Maine from Massachusetts, when he was a Senator from Essex, in 1816, was such an occasion, and he reported the first bill for this purpose, "drawn," says the historian of Maine, "with great ability and skill."* In 1817, he was appointed, together with the late Judge Dawes and late Dr. Dane, "to revise the laws relating to the Courts of Probate, and the settlement of the estates of deceased persons, in one general bill, with such alterations and amendments as were necessary." This great and protracted labor was cheerfully assumed by Mr. Pickering, though the youngest member of the committee, and was accomplished by him with his usual ability and success. Whether the younger or the older in any working committee or body, he was as sure to have the work to do, as others were that he was the best qualified to do it. A similar and yet more extensive service was devolved upon him, on the death of Professor Ashmun, in the revision of the whole body of statutes, in connection with those eminent jurists, Judge Jackson and the late Professor Stearns. The portion of the work which Mr. Pickering undertook was a revision of the statutes relating to the "internal administration of the government," divided into fourteen distinct titles, and subdivided into fifty-eight chapters, some of which contain over two hundred sections. When it is added, that to these chapters was subjoined a great mass of explanatory notes, we may form some judgment of the extent and importance of his labors in this arduous undertaking. He accomplished it in a manner that entitled him to the lasting gratitude of the Commonwealth.

* 9 Law Reporter, 52.

While he was a member of the Senate from the county of Suffolk, in 1829, he took a leading part in the discussion upon the bill respecting manufacturing corporations, which, being based upon principles of justice and sound policy touching the individual liability of stockholders, engaged his strenuous and persevering support. His able speech on that occasion was published, and it affords ample evidence of his thorough knowledge of the subject, and his large and just views of public policy.

In this connection we would observe, that Mr. Pickering was often engaged as counsel before committees of the legislature in important cases. These were interesting to him in proportion as they led him into the investigation and enforcement of great principles of public justice. He never, perhaps, spoke with more signal ability and effect than on the question of a second bridge between Boston and Charlestown, — a question which involved principles and consequences of momentous concern to the people of Massachusetts. His speech was a powerful support of private rights and the public faith, and was alike honorable to his head and his heart.

With this very imperfect notice of Mr. Pickering's civil and legislative services, we pass to the *third* class, including those miscellaneous labors and writings given by him in private and social life. His lively interest in all public improvements, scientific discoveries, and literary undertakings, with his various ability, prompt pen, and ever obliging disposition, pointed him out as the man to be called upon for any sort of intellectual work, needed by societies or individuals. Was any report, memorial, or other document required on any occasion, or was any project to be commended by an exposition of its merits, his judgment and his pen were put in requisition for the purpose. So, too, if any young author

had a manuscript eager, but unfit, for the press, he might be relied on to give it form and comeliness, and to usher it into the world with a preface or introduction. In such cases he was ever content to remain unknown, and to leave the whole literary credit where it was most desired. It would be difficult to say which was the greater, his modesty or his generosity. In some of these various professional and benevolent efforts, he found a most cordial helper in a cherished and admiring friend, whose genius and learning were as practical as his feelings were generous and Christian,—I mean our late eloquent associate, that warm-hearted and noble-minded gentleman, Leverett Saltonstall, — whose delightful image mingles sweetly with the memory of the friend whom he so honored and loved.

These miscellaneous claims upon Mr. Pickering's attention rather increased than diminished upon his removal to Boston. His professional robe could not conceal him from the eye of science, or from the calls of benevolence. Almost immediately his pen was engaged, at the organization of the Boston Society for the Diffusion of Useful Knowledge, in drafting its constitution, writing its first annual report, and commending its objects to the public regard. He was also its first vice-president, Daniel Webster being at its head. Among the latest of these disinterested services was the learned report which he made as chairman of a committee of Boston gentlemen, recommending the purchase and introduction into the country of a telescope of the first class, and illustrating the progress and the importance of astronomical science. These are but instances. His familiar acquaintance with European languages attracted many foreign gentlemen, whose society was so highly valued by him, that he could not fail to give to it much of his time. American scholars, too, always found him ready to listen, and

bountiful both of his time and knowledge. The young student was encouraged to repeat his visits by the manifest delight which Mr. Pickering always took in imparting useful information. Annoying applications for his patronage in matters of a dubious character were, perhaps, unavoidable, and these would sometimes be intruded upon hours which should have been sacred to his repose and recreation.*

We now pass to the *fourth* class, comprehending Mr. Pickering's writings and labors in the cause of ancient learning. We have seen his constant devotion to the Greek and Roman classics. The Hebrew and other Oriental languages also engaged his profound attention. A competent knowledge of the original languages of the Bible he considered indispensable to the theologian. He says, too, of the Hebrew, speaking of Harvard College, that, "with a view to general philology, the student's labors will find as rich a reward in the study of this ancient and curiously formed language, as in any one dialect of the tongues spoken by man." And he wished to see more attention paid to this study in all our colleges.† It was his earnest desire through life, to diffuse the love, promote the study, and raise the standard of classical learning in our country. We can here take only a brief notice of his principal efforts for the promotion of Greek literature.

Mr. Pickering, while he was in Europe, wrote to a member of the college government at Cambridge, proposing, among other improvements, "the adoption of uniformity in grammars and other elementary books at the University." This, whether from his suggestion or not, was soon after carried into execution by the selection of Adam's *Latin Grammar* and the *Gloucester Greek*

* Note D. † Note E.

Grammar to be used in Harvard College. Connected with this subject is the excellent little work, written by Mr. Pickering in 1825, which bears the unpretending title of *Remarks on Greek Grammars*, yet abounds in various information, as interesting as it is learned. The views it presents of the importance of a steady uniformity of elementary books of instruction, and of resisting the spirit of perpetual change in these "instruments of learning," deserve the respectful attention of all our collegiate institutions.

The just tribute which is paid by Mr. Pickering to that "sound Greek scholar," the late President Willard, and to the Emeritus Professor of Greek Literature at Cambridge, whom he ranks among "the most profound scholars of the country," * will long be enjoyed by those who love to remember solid and genuine excellence. The glowing commendation of English literature at the close of these *Remarks* is one of the most eloquent passages of Mr. Pickering's or any other literary discussions.

The translation of Professor Wyttenbach's *Observations on the Importance of Greek Literature and the best Method of studying the Classics*, by Mr. Pickering, was first published in the *North American Review*, for 1819; and was afterwards republished, with an appropriate preface by the translator, and the addition of "an exemplification of the author's method of explaining the classics to his pupils." This was printed at the expense of that kind-hearted patron of letters and zealous agent in founding the Boston Athenæum, the late William S. Shaw, who deserves a grateful remembrance in this metropolis. Professor Wyttenbach, who was regarded in England as the best Continental scholar of Europe, and who, for a great part of his life, had been a practical instructer, was worthy of the attention bestowed upon him by Mr. Pickering.

* Rev. Dr. Popkin.

The results of such a scholar's experience and erudition could not fail to be a valuable guide to those who are engaged in "the arduous but honorable office of instructing our youth in classical learning." We think, too, that his noble example as a self-teacher is worth almost every thing else. His own account of the exertions and progress he made in studying the Greek authors is exceedingly interesting; to which he adds, — "Now, my intelligent pupils, why should not you be able, with the assistance of an instructer, to accomplish as much as I did without one, and by my own industry alone?" We cannot forbear to repeat here, as strikingly applicable to Mr. Pickering's own style and writings, what Professor Wyttenbach observes of the "perfection of Xenophon's style, — which," he says, "has a healthy soundness, an ease, simplicity, and grace, which give it the preference above all others for the introductory studies of boys; whose fresh and youthful minds will there imbibe nothing but the wholesome aliment of the purest of fountains."

In the course of his classical reading in England, Mr. Pickering paid a thorough attention to the pronunciation of Greek, and went over the whole controversy about the reform introduced by Erasmus, as contained in Havercamp's *Sylloge*, and came to the conclusion that Erasmus was right. But a personal acquaintance with several natives of Greece, who arrived here in 1814, led him to a revision and change of his opinion. The result of his investigations on the subject is given in the memoir which he communicated to the American Academy in 1818, and which attracted the marked attention of scholars in Europe; and though it was at first opposed by a distinguished professor of this country, it afterwards received his sanction. It, indeed, bears full evidence of Mr. Pickering's candor and patient research, and is a beautiful

specimen, not only of his extraordinary learning, but of his judgment, taste, ingenuity, and acuteness.*

But Mr. Pickering's great work, his Herculean labor in the cause of classical learning, was his Greek and English Lexicon. How he could have had the courage and resolution to undertake such a work, in the midst of professional toils, is inconceivable without a knowledge of the man. In truth, he thought infinitely less of his own ease than of good to his fellow-men. "A strong conviction," as expressed by himself, "that it would be rendering an essential service to the interests of sound literature in our country, to promote the study of the language of Greece, whose authors will be models in writing as long as her sculptors and architects shall be models in the fine arts," sustained him through all the difficulties of this bold undertaking. He was early convinced of the importance of a Greek lexicon with an English instead of a Latin interpretation, and seeing no prospect of such a work in England, he entered upon the execution of his contemplated plan in 1814. After proceeding alone through about one sixth part of the whole work, he associated with himself the late Dr. Daniel Oliver, whose character both as a scholar and a man rendered him worthy of such a connection. The prospectus was issued in 1820, and the first edition appeared in 1826; the rapid sale of which made it necessary to prepare a second edition much sooner than had been expected. Mr. Pickering, having become sole proprietor of the work, was alone responsible for the second edition, published in 1829, enlarged by the addition of "more than ten thousand *entire* articles and very numerous parts of articles," and greatly improved throughout. The next year it was reprinted,

* Note F.

with additions, at Edinburgh, and recommended to public notice as a "very useful and popular work." In the advertisement to the third edition, this is particularly alluded to, "in order to prevent any misconception or suspicion of plagiarism on the part of the American editor." The preparation of the work for this "new and extensively revised edition, adapted to the more advanced state of Greek studies," was among Mr. Pickering's last labors, and will serve to brighten his highest classical honors. Of his brilliant success in this laborious undertaking my own judgment is of little worth. I give you that of others. An eminent and experienced teacher of classical learning has publicly declared, that "this legacy to American scholars is worthy of the distinguished author," — and that, "after groping amid the vagueness and confusion of Donnegan, it is truly a relief to turn to the order, clearness, and precision of Pickering." A learned professor of the highest authority, himself the author of a Greek and English lexicon of the New Testament, has pronounced "the lexicon of Mr. Pickering, in its present shape, to be the best extant for the use of colleges and schools in the United States, — for which, indeed, it has been specially prepared." A third eminent Greek scholar has told the world, that what Mr. Pickering undertook to do in this great work "has been admirably done." *

With this brief and very imperfect notice of Mr. Pickering's classical achievements, we proceed to the *fifth* class, comprising his publications and labors relating to the English language and literature. We shall attempt little more than to invite attention to their great variety and value. He spread the fruits of his various erudition over the country with unstinted liberality, thinking

* Note G.

only of enriching others and paying the debt which every scholar owes to humanity and learning. The *Monthly Anthology*, the *North American*, the *New York*, the *American Quarterly Reviews*, and the *Annals of Education*, with other periodicals, as well as the daily journals, were honored by the productions of his pen, — productions which, however occasional in their purpose or origin, possess that intrinsic merit which gives them a permanent interest, and entitles them to preservation in some durable form. We trust that in due time they will be gathered up and presented to the world in a manner, and with a biography, worthy of the author.

In all Mr. Pickering's zeal for ancient literature, he never lost sight of his native tongue. He loved the Greek authors ardently for their incomparable excellence, but he valued them the more highly as being the best models of writing to the English scholar. The purity and improvement of the English language in America engaged his early attention. During his residence in England, he began the practice of noting *Americanisms* and expressions of doubtful authority, and as he continued the practice after his return, the collection so swelled under his hands, that he was induced to prepare them for publication, and, in 1815, completed the *Vocabulary*, which formed the first of his learned communications to the American Academy. He afterwards republished it, with additions, for general use; and though he regarded it but as a beginning, yet it was a work of long and patient labor, for which he deserves the gratitude of every American scholar. The work attracted attention even in Germany, where portions of it were translated and published. With its preface and introductory essay, it has served to guard the purity of our language and literature.*

* Note H.

Mr. Pickering had the same general design in his elaborate and learned article on Johnson's English Dictionary, first published in the *American Quarterly Review*, for September, 1828, and justly considered as one of his most interesting and useful publications. Johnson and Walker were regarded by him as holding the first rank in their respective departments in England, and he thought them, of course, entitled to be received as standard authorities by the lexicographers and orthoepists of America.

His excellent article on "Elementary Instruction," published in the *North American Review*, deserves particular notice as being richly imbued with his classical and philosophical spirit, and as containing hints and views important to all who are concerned in the work of education, from the teacher of the alphabet up to the head of a college.

The "Lecture on Telegraphic Language," which he delivered before the Boston Marine Society, of which he was an honorary member, is another beautiful specimen of the familiar and pleasing application of his various learning to the useful purposes of life.

Mr. Pickering's eulogy on our great mathematician, the American La Place, in which he so happily traced the loftiest efforts of philosophical genius, was alike worthy of his subject and of himself, and it will ever rank among the richest treasures of the Academy whose Memoirs it adorns.

But we must hasten to the *sixth* class, which includes Mr. Pickering's studies and labors upon the languages of the American Indians. His more particular attention appears to have been drawn to this subject in 1819, by the publication of Mr. Du Ponceau's Report to the American Philosophical Society, and correspondence with Mr. Heckewelder upon the Indian languages of North America. The extraordinary facts disclosed by this pub-

lication kindled Mr. Pickering's enthusiasm. Though deeply engaged upon his Greek Lexicon, he could not resist the attractions of this new field of labor, so suited to his genius and taste, and in which he might hope to render such important service to science and learning. He stopped not to inquire how profitable the employment might be to himself; it was enough to feel assured that he could labor successfully in extending the boundaries of human knowledge and advancing the improvement of mankind. He immediately wrote for the *North American Review* an able article upon Mr. Du Ponceau's admirable Report, recommending it in the strongest terms to the attention of the learned. In this article he expressed the hope that "the Dictionary of the dialect of the Norridgewock Indians, composed by Father Rasles," would soon be published; and he also suggested "the necessity of establishing, by common consent of the learned, a uniform orthography of the *spoken* languages" of the aborigines of America; both of which laborious undertakings were left for him to accomplish. In 1820 he published in the same Review another ingenious and learned article upon Dr. Jarvis's *Discourse on the Religion of the Indian Tribes of North America;* which attracted the particular attention of Baron William Von Humboldt, of Berlin, who thereupon opened an interesting correspondence with Mr. Pickering on the Indian languages, which continued without interruption till the Baron's death, when Mr. Pickering's portion of the correspondence was deposited in the library of the Royal Academy of Berlin.*

Among the most arduous of Mr. Pickering's incessant labors in this new field of science, and also the least attractive, except from a view of their utility, was the republication of Eliot's *Indian*

* Note I.

Grammar, and Edwards's *Observations on the Mohegan Language*, with introductions and notes. He used to speak of the former as a German labor, and so, too, it was regarded by his friend, Mr. Du Ponceau, who thanked him for the great service he had thereby rendered to the cause of learning. Various other ancient works, relating to the Indian languages, were brought into new light by Mr. Pickering's unwearied care. He prepared Roger Williams's *Vocabulary of the Narraganset Indians* for the Rhode Island Historical Society, and Cotton's *Vocabulary of the Massachusetts Indians*, for the Historical Society of this State. But the greatest work of this description which he undertook was the publication of Father Rasles's Dictionary, already mentioned, of the Norridgewock, or Abnaki, language, with an introductory memoir and notes, — a work which called forth expressions of admiration from those of the learned, both here and in Europe, who could best appreciate the severe toil it must have cost him.

The elaborate article which Mr. Pickering prepared for the *Encyclopædia Americana*, on the Indian languages of North America, is as scientific as it is comprehensive, and exhibits the extent of his researches and the depth of his learning on this copious subject. It was translated into German and published at Leipsic with marks of distinguished honor.

The able and spirited articles published by him in the *New York Review*, in 1826, in reply to an article in the *North American Review*, which had unjustly assailed the philological reputation of two of his most distinguished friends, and traduced the character of the Indians as well as misrepresented their dialects, shows with what vigor he could wield the pen of a Junius, when truth and justice demanded the effort, while it manifests his profound and familiar knowledge of the whole subject.

The preparation of a scheme for reducing *spoken* languages to written forms, contained in his "Essay on a Uniform Orthography for the Indian Languages of North America," communicated to the American Academy in 1820, was, perhaps, of all his labors, the most characteristic of his philological and philosophical genius and skill, and, in its practical consequences, of the highest interest and value. While it facilitates, in a simple and beautiful manner, the formation of written languages and the study of comparative philology, it affords an instrument of incalculable advantage in civilizing and Christianizing the barbarous nations of the earth. It has already been sufficiently tested in Africa, and especially in some of the South Sea islands, as well as among the North American Indians, to rank its author among the distinguished benefactors of mankind.*

In Mr. Pickering's learned article on Adelung's *Survey of all the Known Languages and their Dialects*, published in the *North American Review*, in 1822, he represents the present age as the epoch of a new science, — "the comparative science of languages," which is to be studied, "as we study other parts of human knowledge, by collecting facts, — by ascertaining what languages there are on the globe, and collecting vocabularies, or specimens of them all." According to his estimate of the number of dialects on the globe, they amount to about four thousand. Into this ocean of languages he plunged too deep for me to follow him. I lose sight of him entirely. I cannot fathom his research or enumerate his acquisitions.

We are now brought to the *seventh* class of Mr. Pickering's literary labors, embracing those which relate to comparative philology and ethnography, and, as connected therewith, the Oriental

* Note K.

languages, including those of Africa, Asia, and the vast extent of islands in the Pacific. Here a field was opened to him wide enough for the employment of all his strength and all his time, could he have devoted himself to it. He gave himself to it, as far as he could, with untiring zeal. He hunted for specimens of unwritten dialects, with as much ardor as Audubon hunted for those of unknown birds; and he could give them forms as distinct, if not as beautiful. He had always, indeed, been watchful of opportunities to collect materials for his philological investigations. Hearing, once, of a stranger in Salem who had been among the Yaloffs in Africa, he sought and obtained from him facts and information which enabled him to study the interesting language of that people. Shipmasters, and even common sailors, who had visited strange lands, might be sure, not only of a welcome, but of assistance from him, if they had any facts or knowledge to communicate, illustrative of the inhabitants or their dialects. The publication of Holden's "Narrative" of his captivity and sufferings on Lord North's Island affords an interesting example of such assistance. When the United States Exploring Expedition was in contemplation, Mr. Pickering exerted all his influence to draw the attention of the government, and those more immediately concerned in the undertaking, to "the various native languages of the different tribes of people that might be visited by the expedition." He reminded them of the noble example of the late empress of Russia, and endeavoured to stimulate their curiosity and interest by illustrating the real importance of "this department of knowledge," and by considerations of what was due to the scientific reputation of our country. His correspondence with J. N. Reynolds, Esq., in 1836, on this subject, presented his own enlightened views so clearly, that, if they were duly regarded, we cannot doubt, from the high reputation of the

young philologist who accompanied the expedition,* that results have been attained important to the world and honorable to America.

The hieroglyphics of Egypt and the dialects of the South Sea islands appear to have excited Mr. Pickering's literary enthusiasm in the highest degree. These were fascinating topics, which he was never weary of investigating or discussing. The Chinese language was scarcely less interesting to him. The new views of this language, presented to the world by his friend Mr. Du Ponceau, called forth an able and very learned article from his pen for the *North American Review*, in 1839, which was seized upon, as other of his works had been, as a prize to British literature; and well might British writers be proud of such a prize.† The sister language of Cochin-China (the history of the first American voyage to which country was given to the public through his means) was illustrated by him in another able article, published in 1841, in the same Review. Both articles exhibit, in a striking manner, his familiarity with the profoundest philological speculations.

But I need only point your attention to the eloquent address delivered by him before the American Oriental Society, at their anniversary meeting in 1843, — a society of which he was the soul as well as the head, — to show you the compass, variety, and depth of his philological erudition, and the vast extent of his views and plans for making his erudition useful to the world. The leading objects of this society are "the cultivation of learning in the Asiatic, African, and Polynesian languages," and "the publication of memoirs, translations, vocabularies, and other works relative to these languages." Mr. Pickering's *Memoir on the Language and*

* Horatio Hale, Esq.

† Note L.

Inhabitants of Lord North's Island, presented to the American Academy during the last year of his life, — a memoir as touchingly interesting as it is beautifully written, — affords ample evidence of the noble manner in which, had his life been spared, he would have performed his part in this great literary enterprise.

But I must forbear. To do justice to Mr. Pickering's learned labors would require abundant time, with a genius and a pen kindred to his own. In the cursory view we have taken of them, many of his valuable writings have been wholly overlooked; some of which demand at least a respectful allusion. Of his article, in the *New York Review*, upon the elegant *History of Ferdinand and Isabella*, it is sufficient praise to say that it is worthy of its subject. The comprehensive *Introductory Essay* to Newhall's *Letters on Junius* gives us, in a more concise and pleasing manner than is elsewhere to be found, the history and literature pertaining to the Junius controversy. His biographical sketches of Bowditch, Spurzheim, Du Ponceau, and Peirce, published in the daily journals, are marked by the various excellence of his just, delicate, discriminating pen.* The mention of the last-named friend reminds us of the estimable *History of Harvard University*, which was left unfinished at the lamented author's death, and completed for publication by Mr. Pickering; whose own article on the subject, in the *North American Review*, contains one of the most graphic as well as most just views which have ever appeared of Harvard College.

We must add as a supplementary or *eighth* class of Mr. Pickering's works, his numerous and important letters, addressed to various learned men in this country and in Europe. "For many years," says a well-informed friend, "he maintained a copious correspondence on

* Note M.

matters of jurisprudence, science, and learning, with distinguished names at home and abroad; especially with Mr. Du Ponceau, at Philadelphia; with William Von Humboldt, at Berlin; with Mittermaier, the jurist, at Heidelberg; with Dr. Pritchard, author of the *Physical History of Mankind*, at Bristol; and with Lepsius, the hierologist, who wrote to him from the Pyramids in Egypt." *

All Mr. Pickering's writings are stamped with the excellence of his clear, simple, graceful style, — a style unsurpassed by that of any English author on similar subjects. With proper words in proper places, and bearing the polish of refined taste, it yet flows as naturally as if no thought or labor were bestowed upon it. Almost any one might hope to write in the same manner.

> " Sudet multum, frustraque laboret
> Ausus idem."

The most essential purpose of language is always attained by Mr. Pickering's diction. We see, at once, the ideas he would express, as distinctly as we behold material objects in a clear sky. Nor was his style incapable of rising to an impassioned tone of eloquence, as we have seen on one occasion, at least, when he felt called upon to administer a suitable rebuke to philological presumption. His indignation, if roused, could flash its scorching fires, gentle and benignant as was his whole nature.

But Mr. Pickering's strongest claims upon our admiration and gratitude arise from the exalted spirit and principles which actuated him in all his works. No selfish ends or views ever appear; nothing to set off his powers, or to gain notoriety; while all his important writings are imbued with his rare learning and philan-

* 9 Law Reporter, 66.

thropy, and conspire to establish his fame. He spoke from his inmost heart, when he reminded his brethren of the Oriental Society, in the elegant address just now referred to, that "to be beneficial to our fellow-men" is "the great end of all our intellectual labors." He spoke, too, from his own deep experience, when he declared, that "steady, unremitting labor on subjects of the intellect, like untiring labor of the body upon physical objects, will overcome all obstacles." We see his own high aims in the "incentives" which, at the close of the same address, he so eloquently urged upon his literary associates, — "the love of learning for its own sake, — the reputation of our beloved country, to whom we owe so much, and whom we are all ambitious of elevating to the same height to which other nations have attained by the cultivation of learning." Such was the lofty character of his literature throughout his long career of laborious study.

Mr. Pickering enjoyed excellent health till some time in the summer of 1845, when he experienced the first symptoms of a fatal disease. Under the severe pressure of increasing illness, he pursued his studies, and attended to his various active duties, while he had any bodily strength. His mind continued clear and firm, and he manifested, during all his protracted illness, that patience, gentleness, and Christian resignation, which perfected the example of his life. He died on the fifth day of May, 1846, leaving a widow, an only daughter, and two sons, to mourn their irreparable loss.*

All of you, Gentlemen, had the happiness to know Mr. Pickering in his social as well as literary character, and need not that I should speak to you of his kind and courteous manners, his

* Mrs. Pickering soon followed her lamented husband. She died on the 14th of December, 1846.

sweet temper and disposition, his benevolent virtues, the richness of his conversation, and the delight which his society afforded. He was, as you well know, a man universally respected, — who never lost a friend, and never had an enemy; whom once to know was always to love and esteem.

In domestic life, he was all that could be wished; and, I may add, all that could be imagined in amiable affections. Wisdom and love were delightfully blended in his whole deportment.

Brilliant as is the reputation of the scholar and the author, we lose sight of it in the superior excellence of the man. He was, indeed, a true man. His sensibilities were tender, his whole organization delicate and susceptible, yet always sound and healthful, with nothing of a morbid tendency to unfit him for the active duties of life. Mild and gentle, he yet felt keenly and quickly; and with all his patient forbearance, he was not wanting in spirit and energy to assert his rights. He had a true enthusiasm, without any extravagance. His ardent love of freedom and justice, and his abhorrence of tyranny in all its forms, never partook of fanaticism. With much reserve in expressing his religious feelings, he was profoundly conscientious, and lived in the fear and the love of God.

Truly of him we may say, with Nature's great poet, —

> "His life was gentle, and the elements
> So mixed in him, that Nature might stand up,
> And say to all the world, *This was a man.*"

Christianity, too, might rise up and set her seal of greatness upon him. The fundamental law of Christian greatness he nobly fulfilled. He was, in the highest sense, "the servant of all," — a true philanthropist, the benefactor of his race. His profoundest

erudition and his severest toil were ever subservient to the good of mankind. Usefulness was his glory.

Limited as our view of Mr. Pickering's life has necessarily been, we have not failed to see the wide extent of his active and beneficent influence. Our laws as well as literature bear the impress of his luminous mind. Education acknowledges him as one of her most efficient friends. We have seen him the teacher of teachers, the improver of authors, the enlightener of colleges, the pioneer of civilization, affording a guiding light to all engaged in the acquisition or diffusion of knowledge, from the humblest pupil to the profoundest inquirer, from the classical instructer at home to the herald of Christianity in heathen lands.

Some men's learning is kept, as a standing pool, for their own undisturbed gaze. Mr. Pickering's was a living fountain, gushing out in every direction, fertilizing the country around. Others there are, who think only of rearing from their learning a monument to themselves, caring little for the world. Mr. Pickering thought little of himself, but every thing of the world. So, too, in the use of wealth, some are intent only on its accumulation, as if its value consisted in its bulk, and the distinction thereby produced. Not so the "man of Ross." He spread his wealth wherever he could make it most productive of common blessings. Mr. Pickering was the man of Ross in learning, — scattering his intellectual treasures everywhere, as they were needed to bless his fellow-men.

"The admirable Pickering!" is already the exclamation of fervent gratitude.* Admirable indeed; — not for wonderful talents perverted, or for dazzling, delusive genius; but for fine powers

* Note N.

finely improved, and for noble qualities nobly applied. Admirable for his prodigious industry and learning, and for his sterling integrity and goodness. Admirable as a scholar, as a jurist, as a philologist, as an explorer of truth, as a guide to wisdom and learning, and as a bright exemplar of virtue.

Such an illustrious benefactor inspires the gratitude of all enlightened men. Throughout this western continent, wherever literature and science have their votaries, his memory is cherished. That distinguished American writer, now in France, who has passed his life in reflecting the light of letters from one continent to the other, repeats to us, with his own exalted admiration, the voice of sympathy and of eulogy from the literati of Europe.*

The memory of John Pickering will live throughout the learned world. So long as human language exists and is cultivated, his name will be honored. If he sought not fame, he has found it the more surely, and in a higher degree. His precious reputation rests on ground as solid as his ambition was pure. It will extend with the benign influences of his learning, and it will brighten as it extends.

When will the people at large learn to appreciate their true friends, their real benefactors? The military or political idol of a day kindles their enthusiasm like a blazing meteor, which glares for a moment and is extinguished for ever. Their literary admiration blindly follows brilliant genius, however unsanctified by virtue, and which continues its baleful glare, like the *ignis fatuus*, to mislead and destroy. We would point them to a luminary of the heavens, whose clear light irradiates the path of human duty and human improvement, and guides surely and always to knowledge, virtue, religion, and happiness.

* Mr. Walsh.

NOTES AND ADDITIONS.

THE following passages are from a letter addressed to me by a classmate and intimate friend of Mr. Pickering.

"A love of knowledge characterized Mr. Pickering from youth to old age. Whatever was the subject of his attention, he acquired definite conceptions of it, and these he fixed in his memory. His memory was exceedingly retentive; partly owing, no doubt, to the diligent cultivation of it. If to this love of knowledge and strong memory you add his uncommon diligence, you get the principal explanation of his extraordinary acquisitions. It is, however, to be added, that his mind was of a truly philosophical or scientific cast. He always referred phenomena to principles, so far as he could; considering how far they went in support or in contradiction of principles commonly maintained. His views of every subject were comprehensive. When a partial discussion had led to a conclusion satisfactory to common minds, he would bring forward the considerations which had been overlooked, and thus prevent a too hasty or too confident decision. I can remember this trait of his character from the time when we were in college.

"Mr. Pickering was pure in heart. Few men, if any, have I known as much so. He seemed to have no affinity for evil thoughts, desires, and purposes. They found no harbour in his breast. He had, as I believe, a true and sincere, though unostentatious, piety. He certainly loved man, whom he had seen. He was truly benevolent. To children he showed a tender care and kindness. He was peculiarly liberal to all, and especially to the young, who were seeking to get knowledge. And let it be noted, that this is much more than for the rich man to be liberal in the use of his wealth. Such a one merits great praise, surely; yet he gives what he cannot use for himself. The man of learning does not, indeed, seem to deprive himself of any thing, in helping the student. His own knowledge is not lessened in doing it. But he cannot impart it without giving his time; and this, like his heart's blood. Mr. Pickering would patiently attend to the young student, leaving even his business to do so; and then deprive himself of his sleep at night to finish his business.

"The conversation of such a man must be full of instruction. It was most agreeably so. I think I may say, that, for fifty years past, I have never spent half an hour with Mr. Pickering in which I did not get some interesting or useful information, such as few men could give me.

"In his manners there was a peculiar polish, improved, undoubtedly, by his intercourse with cultivated people abroad. His manners were so simple, as not to arrest attention at first; but so refined and finished, as to bear the closest scrutiny, and to fit him for the most elegant society. He manifested in them the nicest discrimination as to persons. Their foundation was in his good heart and in his respect for the pleasure as well as for the rights of others."

The following is a brief extract from a letter addressed to me by a learned scholar and divine, alluded to in the discourse, who was intimately associated with Mr. Pickering in the American Oriental Society.

"It gave me a great, although a melancholy pleasure, when we last met, that you should request me to recall and write to you my recollections of the late Dr. Pickering. I think it was my particular senior, the late Dr. Joseph McKean, who introduced me to our departed friend, then in the class, as you know, next above us. And this must have been between fifty-two and fifty-three years ago. But from that period I ever entertained toward him the most respectful esteem and regard, and have shared the privilege of his friendship, — a virtuous friendship, productive, from its commencement, of literary and moral benefits. His acquaintance was, to use the phrase of Waller the poet, 'a liberal education.'

"You well remember his gentlemanly deportment in college. You recollect, too, his high and just reputation in the various branches of mathematical science, — a reputation fairly and laboriously earned. But he deserves remembrance at Harvard, also, for being most efficiently engaged in the resuscitation of classical literature. That was at a very low ebb, you know, in the early part of our time there.

"With respect to the extent of his linguistic acquirements, about which you wished me to inform you, I really am not able to give any satisfactory account. I think, however, I can recollect as many as sixteen languages of which we have oc-

casionally conversed, at least. Of late years, the Chinese, in two or three of its dialects, had engaged my lamented friend's attention; and he gave some labor to the Cochin-Chinese; and paid great attention to the progress of discovery in regard to the Egyptian hieroglyphics. The adaptation of his system of expression of sounds by our own alphabet (of which he published a Memoir in the Transactions of the American Academy) excited no small interest. Our missionaries adopted his views in reducing to writing that dialect or derivative of the Malay which is spoken in the Sandwich Islands, having effected the translation into it of the whole Bible. This single thing is highly honorary to our country; and I have wondered that so little has been said respecting it by literary men among us. It must also have a considerable effect. For, as the languages of the Pacific are mostly of Malay origin, it can hardly be predicted to how great an extent the influence of it may reach.

"In regard to ethnology, his attention was drawn to it almost necessarily by the rapid progress made of late years in that branch of information. Indeed, living as he had done in the midst of your Salem merchants and intelligent navigators, — situated as he was, in connection, on the one hand, with the Academy, and presiding in its researches, the results of which became familiar to him, — and on the other, no inattentive observer of the progress of missionary enterprise, in which his own labors, as regards *the philosophy of language*, were brought so often into practical operation, — ethnology became, of necessity almost, a subject of indispensable attention. It was so to me; and it was, therefore, of course, most frequently the theme of our conversations, when we could pass together any portion of our much occupied time. More especially has this been the case in the formation and progress of our American Oriental Society, — an institution happily effected by his consent to become its President, and giving it his valuable labors, influence, and reputation. How it can live and flourish without him remains still to be seen, although, as I hope, his example will have given an impulse, the effect of which may continue.

"One thing should be remembered in respect to classical literature in connection with the late Dr. Pickering. It is this; — his attachment to that literature had a practical object. He did not become a critical scholar for the purpose of vaunting his accuracy in taste, acuteness, or memory. He was ardently and patriotically desirous of raising the scholarship of his country, and qualified himself, and was preparing means for others, to the accomplishment of that end. Hence

his 'lingering in the groves of Academus,' or his intimacy with the ancient 'votaries of the Muses,' was not the reminiscence merely of youthful attachment; but, turning his acquirements into a channel of usefulness, he could contemplate them, not as mementos of wasted labor, but even as fruits of enlightened public spirit.

"How to express my own feelings I find very difficult. Indeed, it is not necessary. You know his moral and intellectual worth, and can appreciate its value, as well as the value of his literary excellence. His was a rare example of true modesty united with distinguished and solid merit, of unassuming but efficient worth, of gentleness of temper joined with decision of character, and of liberal study blended with practical usefulness, good learning with sound common-sense, and thorough honesty of purpose and act; and I may add, of inflexible integrity in private, public, and political life." *

Aided by the recollections of several of Mr. Pickering's most intimate friends, I am enabled to add the following sketch, which, in the absence of an engraved likeness, I am sure, will be acceptable to all his friends.

The personal appearance of Mr. Pickering was striking. It was both dignified and attractive. His stature was tall, and his form rather slender than stout, but well proportioned; yet it was the expression of his countenance, and the fine intellectual cast of his features, which were the distinguishing characteristics of his person. The form of his face was oval, with a remarkably high and ample forehead. His mild, clear, hazel eye was expressive of the gentleness of his nature and the vigor of his intellect; while a straight nose, slightly inclining to the Roman, and a finely formed mouth, added to the regularity of his features. The expression of his countenance, when in repose, was grave and thoughtful; but his eye kindled benignantly, and a benevolent smile played upon his lips, whenever any object of interest came before him. It was this peculiar benignity of expression, joined to an entire freedom from the slightest assumption of superiority in word, look, or manner, which attracted towards him the young, and those who were seeking relief from poverty or distress; while the intellectual refinement and remarkable dignity of his personal appearance and manners commanded the interest and respect of persons in all conditions of life.

* Rev. Dr. Jenks.

ANCESTORS AND FAMILY.

The following additional notices may be interesting to many of Mr. Pickering's friends.

The first-named John Pickering, as stated in Allen's *Biographical Dictionary*, came to New England about 1630, and died at Salem in 1657. "February 7, 1637, he was admitted to the privileges of an inhabitant." He left two sons, John and Jonathan. The latter died in 1729, at the age of 90, without issue. John, born about 1637, married Alice, daughter of William Flint, and died May 5th, 1694, leaving his wife, Alice, and sons, John, Benjamin, and William (who married a Higginson), and daughters, Elizabeth (married to a Nichols), and Hannah (married to John Buttolph). To John he bequeathed "Broad Field by the mill-pond," as stated in Felt's *Annals of Salem* (whence these facts are principally taken), who states also, that "he was frequently of the selectmen, and a capable, enterprising, and public-spirited man." The third John Pickering married Sarah Burrill of Lynn, and died June 19, 1722, aged 64, leaving his wife, Sarah, sons, Theophilus and Timothy, and daughters, Lois (married to Timothy Orne), Sarah (married to Joseph Hardy), and Eunice (married to her cousin, William Pickering). "He was selectman and representative in the legislature. His decease was a loss to the community."

Timothy Pickering married Mary Wingate, and died June 7th, 1778, aged 75, leaving his wife, Mary, sons, John and Timothy, and daughters, Sarah, Mary, Lydia, Elizabeth, Lois, Eunice, and Lucia; all of whom were married (except John), and had numerous descendants. "Deacon Timothy Pickering sustained principal offices in town, and was an intelligent, active, and useful man." His elder brother, Theophilus, deserves notice as one of the remarkable men of his time. He was educated at Harvard College, graduating in 1719, and settled in the ministry in that part of Ipswich which is now Essex. He was remarkable for his bodily strength, mechanical ingenuity, and theological ability. Tradition says, that a certain man, who had the presumption to challenge him to a wrestle, was not only thrown by him at once, but thrown over the wall. His friends thought him equally successful against some of the New Lights of that day, who wrestled with him in religious controversy. He died, unmarried, at the age of forty-seven.

The seven daughters of Timothy Pickering were married as follows: Sarah, to John Clarke (parents of the late Rev. John Clarke of Boston, and Mrs. Francis Cabot); Mary, *first*, to the Rev. Dudley Leavitt (parents of the late Mrs. Dr. Joseph Orne, Mrs. William Pickman, and Mrs. Isaac White, whose daughter, Sarah, became Mrs. Pickering), — *second*, to the late Chief-Justice Nathaniel Peaslee Sargeant; Lydia, to George Williams (parents of the late Samuel Williams, consul, &c., Mrs. Pratt, Mrs. Lyman, and others); Elizabeth, to John Gardner (parents of the late Samuel P. Gardner and Mrs. Blanchard); Lois, to John Gooll (parents of Mrs. Judge Putnam, who, with her widowed mother, once formed part of the family of her uncle, the Hon. John Pickering); Eunice, to her cousin, Paine Wingate, Senator of the United States from New Hampshire (parents of George Wingate, a graduate of Harvard College in 1796, and other children); Lucia, to Israel Dodge (parents of the late Pickering Dodge, Mrs. Stone, Mrs. Devereux, and others). The members of this family were remarkable for their longevity. Mrs. Wingate's age a little exceeded one hundred years, and her husband was for some years the oldest surviving graduate of Harvard College.

The few particulars now mentioned may be sufficient to indicate these wide-spreading branches of the Pickering family.

Colonel Timothy Pickering, who was born in 1745, and died in 1829, married Rebecca White, and they had first eight sons, and then twin daughters, Mary and Elizabeth. Their eighth son was Octavius Pickering, well known as a reporter of decisions of the Supreme Judicial Court of Massachusetts. Of the father, whose exalted character as a patriot and statesman is indelibly impressed on the history of his country, we need say nothing here, except to notice one of his most gratifying honors, which became intimately connected with the subject of our eulogy. Washington, on retiring from the presidency, in 1797, presented Colonel Pickering, his fellow-soldier and friend, with a splendid piece of silver plate, from his own service, as a memorial of his cordial esteem and confidence. This treasure, of priceless value, was bequeathed by the Colonel to his son, John, and by him to his daughter, Mary Orne Pickering. May it always find possessors equally worthy of such a treasure!

Mr. Pickering's two sons, John and Henry White, graduated at Harvard University, the one in 1830, the other in 1831; both are happily settled in Boston, the former in the profession of the law, the latter in commercial business. The proprietor of the ancestral estate, in Salem, is still John Pickering.

NOTE A. Page xxxi.

Mr. Pickering was a representative from Salem in the legislature of Massachusetts, in 1812 and 1813, and again in 1826; a Senator from the county of Essex in 1815 and 1816, and from the county of Suffolk in 1829, and a member of the Executive Council in 1818. He received the degree of LL. D. in 1822, from Bowdoin College, and, in 1835, from Harvard University. The following is copied from the *Law Reporter* already referred to.

"The number of societies, both at home and abroad, of which he was an honored member, attests the wide-spread recognition of his merits. He was President of the American Academy of Arts and Sciences; President of the American Oriental Society; Foreign Secretary of the American Antiquarian Society; Fellow of the Massachusetts Historical Society; of the American Ethnological Society; of the American Philosophical Society; honorary member of the Historical Societies of New Hampshire, of New York, of Pennsylvania, of Rhode Island, of Michigan, of Maryland, of Georgia; of the National Institution for the Promotion of Science; of the American Statistical Association; of the Northern Academy of Arts and Sciences, Hanover, New Hampshire; of the Society for the Promotion of Legal Knowledge, Philadelphia; corresponding member of the Royal Academy of Sciences at Berlin; of the Oriental Society at Paris; of the Academy of Sciences and Letters at Palermo; of the Antiquarian Society at Athens; of the Royal Northern Antiquarian Society at Copenhagen; and titular member of the French Society of Universal Statistics."

NOTE B. Page xxxv.

The Report referred to was made to the Board of Overseers at their annual meeting in January, 1841. The following brief extract will sufficiently indicate its character.

"Superficial observers, who measure the value of education by its direct capacity of being turned into money, or the immediate supply of the physical wants of man, and not by its moral effects on the constituent elements of human society,

are frequently disposed to undervalue some of the departments of knowledge, — particularly ancient literature, — which have always been cherished, and justly so, as an essential part of the university course. Those departments of study are too often stigmatized as antiquated, and not adapted to the 'spirit of the age'; while an urgent call is made for what is designated by the vague and undefined name of useful knowledge. Such persons seem to mistake the true purpose of a university education; which is not to qualify a young man for any one particular profession or business, but to develope the powers of his mind, and to store it with all that general information in science and literature which shall be really useful to him, by its permanent influence in any station in life."

NOTE C. Page xxxvi.

In the *Law Reporter*, before referred to, it is justly said of Mr. Pickering, "that he was a thorough, hard-working lawyer, for the greater part of his days in *full practice*, constant at his office, attentive to all the concerns of business, and to what may be called the humilities of his profession. He was faithful, conscientious, and careful in all that he did; nor did his zeal for the interests committed to his care ever betray him beyond the golden mean of duty. The law, in his hands, was a shield for defence, and never a sword with which to thrust at his adversary. His preparations for arguments in court were marked by peculiar care; his brief was very elaborate. On questions of law he was learned and profound, but his manner in court was excelled by his matter. The experience of his long life never enabled him to overcome the native, childlike diffidence which made him shrink from public displays. He developed his views with clearness, and an invariable regard to their logical sequence; but he did not press them home by energy of manner or any of the ardors of eloquence.

"His mind was rather judicial than forensic in its cast. He was better able to discern the right than to make the wrong appear the better reason. He was not a legal athlete, snuffing new vigor in the hoarse strifes of the bar, and regarding success alone; but a faithful counsellor, solicitous for his client, and for justice too. It was this character that led him to contemplate the law as a science, and to study its improvement and elevation. He could not look upon it merely as a

means of earning money. He gave much of his time to its generous culture. From the walks of practice he ascended to the heights of jurisprudence, embracing within his observation the systems of other countries. His contributions to this department illustrate the spirit and extent of his inquiries."

Thus was the law the laborious as well as honorable business of Mr. Pickering's life. Literature, however intently pursued, was his amusement, his delightful recreation. And this he enjoyed chiefly at home in the midst of his family. Besides the fine law library at his office, he had at his house a large miscellaneous one of choice books which gratified his highest wishes. But his love for books did not seclude him from society or from domestic enjoyment. The claims of hospitality as well as of his family were sacredly regarded by him; and when these encroached on hours which he had assigned to some favorite pursuit, the early morning and the late evening would find him redeeming the time which had been cheerfully given to the duties of social and domestic life. His extraordinary faculty of abstraction, the readiness with which his mind could turn from one subject to another, his unwearied industry, and a peculiarly calm and happy temperament, all united in enabling him to accomplish what he did in the conflicting pursuits of literature and the law.

Note D. Page xliv.

It is not easy to give a just impression of the variety and extent of Mr. Pickering's kind and gratuitous services. At the moment the writer was engaged upon this part of his subject, he received a letter from a friend, now a distinguished author, containing the following grateful acknowledgment of assistance afforded to himself. "Mr. Pickering," he observes, "was in my eye the model of a high-bred, courtly, and refined gentleman, — profound, yet unpretending. I have gathered much wisdom from his lips, as well as his writings; the first compositions I ever put to press were revised by him." Many an author has been ready to acknowledge much more than this, and with equal pleasure. Mr. Pickering might have justly applied to himself the remark which he made of his friend, Mr. Du Ponceau, that, if he had been ambitious to claim all that he was entitled to, "he might in numberless instances have said, in the spirit of the Roman poet, — *Hos ego versiculos feci; tulit alter honores.*"

In the pursuits of the young student Mr. Pickering always manifested a lively interest, and the young were strongly attracted to him. With some of the gifted students of our University he maintained a literary correspondence. Among those of them who have passed away may be named Samuel Harris, with whom, many years ago, he corresponded on the Hebrew and other learned languages, and whose untimely death deprived the country of one who promised to be an accomplished Oriental scholar.

We must not omit all notice of one of the most laborious of Mr. Pickering's undertakings in this class of services. Not long before his removal to Boston, a protracted series of arduous and perplexing duties was imposed upon him as chairman of a committee "appointed to inquire into the practicability and expediency of establishing manufactures in Salem." His elaborate and able report on the subject was published in 1826, and affords striking evidence of his practical, as well as his intellectual, talents.

A more characteristic instance of generous service occurs to our recollection, which deserves mention as manifesting his ever vigilant attention to the interests of learning. He promoted and prepared an ably written memorial to Congress, from the principal citizens of Salem, in 1820, for the reduction of duties on the importation of certain foreign books. It was the first presented to the government on that subject, though followed by others from various learned bodies, the object being considered important to the cause of literature and science in the United States.

Note E. Page xliv.

Mr. Pickering, in his Address before the American Oriental Society, observes, "that the various new sources of information which modern perseverance and zeal have opened to us have materially extended the boundaries of a liberal education; and it has become indispensable to unite with our Greek and Roman a portion of Oriental learning. If there were no other motive for the pursuit of this branch of knowledge, there would be a sufficient one in the fact, that the great parent language of India, the *Sanscrit*, is now found to be so extensively incorporated into the Greek, Latin, and other languages of Europe, and, above all, in those which we consider as peculiarly belonging to the Teutonic or German family, that no

man can claim to be a philologist without some acquaintance with that extraordinary and most perfect of the known tongues."

In the *Law Reporter*, before referred to (p. 62), it is stated (doubtless within bounds), that Mr. Pickering "was familiar with the French, Portuguese, Italian, Spanish, German, Romaic, Greek, and Latin; was well acquainted with the Dutch, Swedish, Danish, and Hebrew; and had explored, with various degrees of care, the Arabic, Turkish, Syriac, Persian, Coptic, Sanscrit, Chinese, Cochin-Chinese, Russian, Egyptian hieroglyphics, the Malay in several dialects, and particularly the Indian languages of America and of the Polynesian islands."

Of late years, the Egyptian hieroglyphics possessed for Mr. Pickering a fascinating interest. The history of the Egyptians, from the era of Herodotus down to the latest discoveries of Lepsius, would have enlisted his enthusiasm as a lover of literature and science; yet it was in connection with his cherished pursuit, the study of languages, that the hieroglyphical inscriptions enchained his attention,— speaking, as they do, through the medium of Champollion's interpretation, a language older than all othe rs bythe long interval of ages.

Note F. Page xlvii.

Mr. Pickering's memoir *On the Pronunciation of the Greek Language* was hailed by the Greeks "as a vindication of their national honor"; and Asopius, a learned Greek (a poet and professor at the University of the Seven Islands), was so much gratified by reading it, that he sent Mr. Pickering a copy of one of the best specimens of Romaic literature, as a token of his gratitude.

The *North American Review*, for June, 1819, contains a profound and very learned article upon this Memoir, which the scholar who is curious in Greek literature will find exceedingly interesting.

NOTE G. Page xlviii.

As we wish to give a just view of the character and merits of Mr. Pickering's great work, we adduce here some passages from several of the numerous other critical notices of it which have appeared in various parts of the country, and which extol it in the same high tone of commendation as those before referred to. " Liddell and Scott's," it is said, " is the only work now extant that can come in competition with Pickering's." And it is added, — " We do not hesitate to give the preference to Pickering's, because we regard it as better suited for use in colleges and schools." Mr. Pickering himself, in the Preface to his Lexicon, speaks of Liddell and Scott's as " a most valuable and important acquisition to all who wish to study Greek critically." He was, indeed, the last man to depreciate the literary works of another. But his object was, to make the best lexicon for the students of Greek generally. This, for our country, appeared to be the desirable object. Those comparatively few scholars who pursue their Greek studies to great extent and exactness will of course supply themselves with various lexicons. That Mr. Pickering succeeded in his object is abundantly manifest.

A learned professor (who speaks to us through the *Hampshire and Franklin Express*) says of Mr. Pickering's Lexicon: — " The recent edition is a new work, restudied and rewritten, with the aid of all the best works of the kind which European scholars have so multiplied during the interval of ten or fifteen years which have elapsed since the appearance of the first. And irrespective of national preferences and grateful recollections, all prejudices apart, it is a work of vast labor, great learning, excellent judgment, and elegant taste ; it is, as we have said, in its kind and for its use, a finished work. It is not, of course, as full and complete as its larger rival ; though, on some points, — as, for instance, the *prepositions* and *particles*, — it will bear a favorable comparison in regard to completeness. In the discriminating and felicitous *translation* of many and difficult passages, it is without a rival. The quantities of the doubtful vowels are marked with great care and accuracy. The derived tenses of the verb are exhibited in distinct articles, much to the convenience of the young student. It illustrates the words and idioms of the *New Testament* more fully than any other lexicon of the classic Greek now in use. In short, it accomplishes what it professes to ; and to enumerate its excellencies

were but to repeat, as real and splendid achievements, what are set forth as modest claims in the editor's Preface."

"Of all Greek lexicons which have hitherto appeared," says another competent judge (through the *Connecticut Weekly Review*), "we think Pickering's will be most useful to all classes of students. It will be the lexicon for the school-desk, and for the collegian's study; and it will be especially prized by the teacher who wishes thoroughly to capacitate himself to communicate to others a critical knowledge of this ancient language by the simplest method. It is sufficiently copious, and has evidently been prepared with great care. We give it our unqualified recommendation."

A long list of similar testimonials might be given, but it is sufficient to add one more, taken from a recent number of the *Christian Examiner*, and evidently proceeding from a high source.

"The lexicon, in its present form, is in every respect an excellent one. It does great honor to the ability, unwearied industry, and vast attainments of its author. It is particularly adapted to the range of Greek works studied in the schools and colleges of the United States; and American editions of the classics have been specially referred to. It is well suited to the younger scholars, inasmuch as it contains, in alphabetical order, the oblique cases and the principal dialectical or unusual forms of anomalous nouns, adjectives, and pronouns, and the principal tenses of anomalous verbs. But Mr. Pickering did not limit his task to this special object. He used all the aids which the recent works in philology and lexicography published in Europe, particularly in Germany, furnished him. Besides the contributions of Dunbar, and Liddell and Scott, Mr. Pickering diligently consulted the work of Passow, both in the original German edition, and in the new one edited by Rost and Palm, the lexicon of Jacobitz and Seidler, the excellent one of Pape, those of Schneider and Riemer, besides numerous lexicons and verbal indexes to particular authors, and the new Paris edition, not yet completed, of Stephens's *Thesaurus*. Besides these lexicographical works, Mr. Pickering availed himself of special treatises on the various branches of Hellenic antiquities. It is sufficient to mention Boeckh on the *Public Economy of Athens*, and Platner on the *Attic Process*, both of which, while explaining the financial, political, judicial, and other problems growing out of the history of the Athenian commonwealth, have at the same time supplied important materials for the lexicographer. Mr. Pickering's professional learning has been of great assistance to him in that portion of the lexicon which

contains the technical terms of Athenian law and the administration of justice. We have found his lexicon excellent for the Attic orators. Indeed, we have sometimes found words in it which are wanting in the larger work of Liddell and Scott. Mr. Pickering's definitions are concise and exact; and though his plan did not admit of a full historical development of every word, upon the principles partially carried into effect by Passow, yet the reader of Greek literature will rarely turn away unsatisfied.

"The work is very handsomely and accurately printed. It extends to 1456 pages, with three columns on a page, containing thus a vast amount of matter, with a remarkable economy of space. It is in every respect a very convenient and desirable book. F."

NOTE H. Page xlix.

The following passage from the learned article in the *North American Review*, on Mr. Pickering's memoir of the Greek language (referred to in a preceding note), contains an allusion to his *Vocabulary*, with its title given at length. We therefore adopt it here.

"The author of this memoir is not a mere scholar. Like others of his countrymen who have deserved well of letters, he has been obliged to prosecute his studies, 'not in the soft obscurities of retirement, or under the shelter of academic bowers,' but amidst the inconveniences and distractions of public life, and the fatigues of his honorable profession. He is already well known to our readers as the author of a *Vocabulary of Words and Phrases which have been supposed to be Peculiar to the United States of America. To which is prefixed an Essay on the Present State of the English Language in the United States.* And having thus done no little service to American literature, he is the first to call the attention of scholars in this country to the proper pronunciation of the Greek."

Note I. Page li.

"If, indeed," says Mr. Pickering, in his review of Dr. Jarvis's *Discourse*, "our only motive in the study of languages were to repay ourselves by the stores of learning locked up in them, we should be poorly rewarded for the labor of investigating the Indian dialects; but if we wish to study human speech as a science, just as we do other sciences, by ascertaining all the facts or phenomena, and proceeding to generalize and class those facts for the purpose of advancing human knowledge; in short, if what is called philosophical grammar is of any use whatever, then it is indispensable to the philologist of comprehensive views to possess a knowledge of as many facts or phenomena of language as possible; and these neglected dialects of our own continent certainly do offer to the philosophical inquirer some of the most curious and interesting facts of any languages with which we are acquainted."

"Until within a few years past," he observes, in his memoir on a uniform orthography for the Indian languages of North America, "these neglected dialects, like the devoted race of men who have spoken them for so many ages, and who have been stripped of almost every fragment of their paternal inheritance except their language, have incurred only the contempt of the people of Europe and their descendants on this continent; all of whom, with less justice than is commonly supposed, have proudly boasted of their own more cultivated languages as well as more civilized manners."

"Mr. Du Ponceau," says Mr. Pickering, in his review of the *Dissertation on the Nature and Character of the Chinese System of Writing*, "was the first writer who took a comprehensive view of the languages of the whole continent, and established the general conclusion, that the American dialects, from one extremity of the continent to the other (with perhaps some exceptions), form a distinct class or family; which, from their highly compounded character, he has happily designated by the term *polysynthetic*. Now these complex American dialects are at one extremity of the series or chain of human languages; while at the other we find the very simple and inartificial language of China; these two extremes, when contrasted with each other, presenting this extraordinary phenomenon, that the savage tribes of the New World, though destitute of all literature and even of written languages, are found to be in possession of highly complex and artificial forms of speech, — which would seem to be the result of cultivation, — while in the Old

World, the ingenious Chinese who were civilized and had a national literature even before the glorious days of Greece and Rome, have for four thousand years had an extremely simple, not to say rude and inartificial, language, that, according to the common theories, seems to be the infancy of human speech. This phenomenon well deserves the consideration of the philosophical inquirer, and especially of those speculatists who have assumed a certain necessary connection between what is considered the refined or artificial state of a language and the cultivation of the human race."

In reference to "the able and philosophical investigations of Mr. Du Ponceau, and the interesting work of his experienced and worthy fellow-laborer, the Rev. Mr. Heckewelder," Mr. Pickering, in his memoir just now mentioned, says:— "For my own part, I acknowledge that they have occasioned my taking a deeper interest in this apparently dry and barren subject, than I would have believed to be possible in any one, however devoted he might be to philological pursuits; and I have in consequence been for a time allured from old and favorite studies, to which I had intended to allot the whole of that little leisure which I could spare from the duties of my profession."

The original manuscript of the dictionary of Father Rasles or Râle (for his name is spelt both ways) was found among his papers after his death in 1724, and came into the possession of Harvard College. "Of all the memorials of the aboriginal languages in the Northern Atlantic portion of America," observes Mr. Pickering, in his introductory memoir, "the following Dictionary of the Abnaki language (or Abenaqui, as it is often called, after the French writers) is now among the most important." Mr. Pickering spared no labor in its publication. It may be found in the first volume, new series, of the *Memoirs of the American Academy*, extending over more than two hundred quarto pages.

Of "the printed books relating to these languages," adds Mr. Pickering, "the wonderful work of Eliot, 'the apostle,' I mean his entire translation of the Old and New Testaments, and his Grammar of the Massachusetts Indian language, are in every respect the most remarkable." Mr. Pickering's admirable republication of this grammar was entitled,—"A New Edition with Notes and Observations, by Peter S. Du Ponceau, LL. D., and an Introduction and Supplementary Observations by John Pickering." It first appeared in the *Massachusetts Historical Collections*. So also did the "New Edition, with Notes by John Pickering," of Dr. Edwards's *Observations on the Mohegan Language*.

Note K. Page liii.

Those who feel an interest in the subject will not fail to recur to Mr. Pickering's beautiful philosophical essay *On the Adoption of a Uniform Orthography for the Indian Languages of North America*, contained in the fourth volume of the *Memoirs of the American Academy.* Its perusal, indeed, would in most minds create an interest, if one is not already felt.

Professor Robinson, in his *Biblical Researches in Palestine*, &c. (Vol. I., p. x.), upon stating that the Syrian mission at Jerusalem had adopted "the system proposed by Mr. Pickering for the Indian languages," observes: — "Two motives led to a preference of this system; first, its own intrinsic merits, and facility of adaptation; and secondly, the fact, that it was already extensively in use throughout Europe and the United States, in writing the aboriginal names in North America and the South Sea islands; so that, by thus adopting it for the Oriental languages, a uniformity of orthography would be secured among the missions, and also in the publications of the American Board."

After referring to the "Essay, &c., by John Pickering," Professor Robinson adds: — "The Indian languages of North America and of the islands of the Pacific have mostly been reduced to writing according to this simple system."

The following is a list of the principal languages which have been reduced to writing, on the principles of Mr. Pickering's system, by missionaries of the American Board of Commissioners for Foreign Missions, and in which books have actually been printed: — the Greybo and Gaboon, in *Africa;* the Hawaiian, *Sandwich Islands;* the Choctaw, Creek, Osage, Pawnee, Seneca, Abenaquis, Ojibwa, Ottawa, Sioux, and Nez Perces, *North America.*

Note L. Page lv.

Mr. Pickering, in his biographical notice of Mr. Du Ponceau, thus describes the new views presented in his *Dissertation on the Nature and Character of the Chinese System of Writing.* "He published a few years ago a work unfolding new views of the remarkable language of China, which has been long enveloped in

almost as much mystery as the hieroglyphic system of ancient Egypt. Not agreeing with those who held the opinion, that the Chinese language is *ideographic*, that is, that the *written* characters denote *ideas* of things, and do not represent *spoken* words, — so that different nations of the East could understand each other by the *writing*, when they could not by speaking, — just as the Arabic numerals are understood alike, for example, by a Frenchman and Englishman, when written, though not when spoken, — contesting this opinion, we say, Mr. Du Ponceau boldly assumes the position, that the Chinese must be like other languages, and that the written characters, or words, represent *spoken* words or sounds, as in all the languages of Europe. The sinologists of the Old World are acquainted with his book, but are not prepared to adopt his views, though some of them are silently making use of his terminology, and so far give countenance to his results. Yet, if he is wrong, and if the language of the Chinese is not like other languages of the *human race* in the particular in question, the fact will present a more extraordinary phenomenon than any of the extraordinary characteristics hitherto known of that singular people."

Having reviewed this important work immediately after its publication, with the profoundest attention to the subject, Mr. Pickering naturally felt much curiosity to observe in what manner Mr. Du Ponceau's new and striking views of the Chinese language would be received by European scholars. "Knowing the force of the opinions which have been maintained by them for more than two centuries, respecting the language of the singular people of the 'Celestial empire,' we were prepared," say the North American Reviewers, in their article on the Cochin-Chinese language, "for a total dissent from the doctrines of our learned author, if not a positive and direct attempt to refute them." "When we saw announced in the contents of that long-established and able journal, the *London Monthly Review*, for December, 1840, an article expressly upon this work, we felt no little impatience to see the article itself, which we had understood to be highly commendatory of Mr. Du Ponceau's work, and in perfect coincidence with his views. Upon opening the London journal, what was our astonishment to find, at the first glance, that the review was taken from our own article; and, upon a closer comparison, to discover, that, with the exception of a few paragraphs (which in their original form had American badges attached to them), *the entire London article was a reprint, without any acknowledgment, from our own pages!*"

NOTE M. Page lvi.

PETER S. DU PONCEAU, LL. D.

A few passages from Mr. Pickering's interesting notice of the life and character of his most distinguished literary and personal friend cannot be out of place here.* They were doubtless first attracted to each other by their rare erudition, but their friendship was cemented by that purity of heart and delicacy of taste and of feeling in which they so entirely sympathized. Their correspondence, which was commenced in 1818, and terminated only by death, was as intimate and delightful as it was learned.

Mr. Du Ponceau died in April, 1843. "To the writer of this notice," says Mr. Pickering, "for whom he had long cherished an affection almost parental, his death is an irreparable loss; a long-tried friend and counsellor is no more!"

"Mr. Du Ponceau was born on the third day of June, 1760, in the Isle of Ré, which lies a few miles from the coast of La Vendée, in France." His philological genius, like Mr. Pickering's, discovered itself very early, and in his case appears to have determined his lot in life. "As the smallest circumstances in the history of such minds as his," continues Mr. Pickering, "cannot but be interesting, we will here add, — we have heard him state, that, while a child of only six years of age, his curiosity to know something of the English language was intensely excited by his accidentally meeting with a single torn leaf of an English book, in which he discovered the strange letters *k* and *w*, — for such they were to a child who had never seen them in any book in his own language; and this circumstance, trifling as it may appear, first directed his attention to our language. At that time, General Conway, who was afterwards somewhat conspicuous, during the American Revolution, as a member of the British House of Commons, had the command of a regiment stationed in the Isle of Ré, and, being struck with the remarkable points of character in a child of so tender an age, and with his aptitude for the study of languages, obligingly took pains to instruct him in English; and such was his progress, that in a very short time he was able to read Milton, Shakspeare, and other English classics, whose works are far beyond the grasp of ordinary youthful minds. As he proceeded, he became so delighted with the great English

* First published in the *Boston Courier*, April 8, 1843.

masters, that he never afterwards acquired a truly national fondness for the poetry of France."

When the well-known Baron Steuben was in Paris, on his way to the United States to join the American army, and, "being unacquainted with the English language, was making inquiries for some young man, who could speak English, to accompany him as his secretary, he was informed of young Du Ponceau, who happened then to be in Paris, and an arrangement was made with him accordingly. We recollect," adds Mr. Pickering, "to have heard Mr. Du Ponceau say, that, at that time, though he had never been out of France, he understood and could speak English as perfectly as he ever could afterwards."

"Mr. Du Ponceau left Paris in the suite of Baron Steuben for the United States, fired with the ardor of youth, and full of zeal in the cause of American liberty, which he ever fondly cherished. He landed at Portsmouth, New Hampshire, on the first day of December, 1777; an event in his life which he often alluded to with lively interest."

"At the close of the war, he had fixed his mind on the profession of the law, — and many years did not elapse before he attained the first rank." — "His purity of purpose, incorruptible integrity, and independence, never suffered him, during periods of the highest political excitement, to deviate from the sacred duty of a faithful legal adviser, even when pressed by the almost irresistible influence of national feeling or partisan principles, or — what in our own time is a still stronger stimulant — the corrupting lure of political advancement."

"During the latter part of his life, after he had acquired a competent fortune by his profession, he devoted most of his time to his favorite study of *general philology*, a science which has employed the first intellects of the Old World, from the time of the great Leibnitz to that of the late illustrious Baron William Humboldt in our own time; and there can be little, if any doubt, that the labors of Mr. Du Ponceau in that noble, but boundless field, have, among the profound scholars of Europe, contributed more to establish our reputation for solid erudition than those of any other individual in this country."

Mr. Du Ponceau most heartily reciprocated the admiration entertained of him by Mr. Pickering, whom he regarded as an honor and an ornament to his country, and often alluded to the high estimation in which he was held by the first philologists and ethnographers of the Old World, — the Humboldts and the Prichards, who sought and appreciated his correspondence.

Note N. Page lx.

"In contemplating the variety, the universality, of his attainments, the mind involuntarily exclaims, 'The admirable Pickering!' He seems, indeed, to have run the whole round of knowledge."

"The death of one thus variously connected is no common sorrow. Beyond the immediate circle of family and friends, he will be mourned by the bar, amongst whom his daily life was passed; by the municipality of Boston, whose legal adviser he was; by clients who depended upon his counsels; by all good citizens, who were charmed by the abounding virtues of his private life; by his country, who will cherish his name more than gold or silver; by the distant islands of the Pacific, who will bless his labors in every written word that they read; finally, by the company of jurists and scholars throughout the world." — 9 *Law Reporter*, pp. 61, 66.

MEMOIRS

OF THE

AMERICAN ACADEMY.

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I.

CHLORIS BOREALI-AMERICANA: *Illustrations of New, Rare, or otherwise Interesting North American Plants, selected chiefly from those recently brought into Cultivation at the Botanic Garden of Harvard University, Cambridge.*

BY ASA GRAY, M. D.,

FISHER PROFESSOR OF NATURAL HISTORY, ETC.

DECADE I.

(*Communicated to the Academy, January 27th,* 1846.)

THIS memoir is designed to contribute in some degree to the advancement of North American botany, by illustrating several new or scarcely known plants, especially those of which the floral structure, natural affinities, or generic characters have hitherto been imperfectly made out, or in some respects misapprehended. The subjects chosen for illustration in this first decade are none of them

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absolutely new to botanists. Two of them, indeed, have been already figured, but without the analyses and details requisite to elucidate their real structure, and settle the questions upon which their ordinal or generic collocation depends. The others, with one exception, belong to genera or species which have not yet been published in any systematic work, at least under their proper names, or which, like the rare Schweinitzia, have hitherto been very imperfectly characterized. Certain plants, which have been first introduced into cultivation at the Botanic Garden under my charge, and which are of special horticultural rather than of strict botanical interest, may also be deemed worthy of occasional illustration. Of this kind is the Gaillardia, represented in Tab. IV.

It will be noticed that the plant which forms the subject of the first illustration is given under a name different from that which, if my conclusions are correctly drawn, it must hereafter bear. This is explained by the fact, that the plate was engraved and the impressions taken long before I was able to make the comparisons which rendered the change of name inevitable.

OAKESIA CONRADII, *Tuckerm.*

TAB. I.

OAKESIA, *Tuckerman in Lond. Journ. Bot.*, 1. *p.* 446.

Tuckermania, *Klotzsch.*

Flores dioici seu polygami, capitati, singuli bracteolis nempe squamis 5–6 membranaceo-scariosis concavis bi–trifariam imbricatis suffulti. Perigonium proprium nullum. *Masc.* Stamina 3, rarius 4: filamenta filiformia: antheræ versatiles, subgloboso-didymæ, biloculares, loculis per rimam longitudinaliter dehiscentibus. Pistilli rudimentum sæpissime nullum. *Fœm.* Ovarium obovoideum, triloculare, raro quinque–sexloculare, loculis uniovulatis: ovulum anatropum ex angulo interno erectum: stylus tenuis, brevi-exsertus, apice trifidus, nunc quadri–quinquefidus; laciniis subulatis, patentibus, sæpius uni–bidentatis, intus stigmatosis. Discus hypogynus (ut in ordine!) plane nullus. *Hermaph.* Pistillum fl. fœminei. Stamina 3, omnia antherifera, vel 1–2 ad mera vestigia reducta: antheræ sæpius dimidiatim uniloculares. Drupa parva, subglobosa, sicca (epicarpio pertenui), tripyrena, nunc quadri–quinquepyrena; pyrenis cartilagineis, semine erecto impletis. Embryo gracilis, in axi albuminis carnosi orthotropus, eodem brevior: radicula infera: cotyledonibus brevissimis.

Fruticulus ericoideus depressus, ramosissimus, diffu-

sus; foliis ter–quaternatim verticillatis sparsisve, confertis, patentibus, linearibus, sub lente hispidulo-scabris, convexo-planis, subtus sulco profunde exaratis. Flores in capitulis terminalibus multibracteatis digesti, singuli in axilla bracteæ aridæ squamæformis arcte sessiles. Squamæ fulvæ: stamina longe exserta stylique rubiginosi.

O. Conradii, *Tuckerman, l. c.; Hook. Ic. Pl.* 6. *t.* 531.

Empetrum Conradii, *Torr. in Ann. Lyc. Nat. Hist. New York*, 4. *p.* 83 (1837); *Bigel. Fl Bost., ed.* 3. *p.* 393.
Tuckermania Conradii, *Klotzsch in Erichs. Archiv., Apr.* 1842, *p.* 248.
Corema Conradii, *Torr. & Gray, ined.*

Hab. In arenosis "Pine barrens" dictis, Novæ Cæsareæ, ubi primum detexit beat. *S. W. Conrad,* posthac legerunt *Rafinesque, Torrey,* et *Knieskern.* Circa Plymouth Massachusettensium, *Oakes, Tuckerman, Russell,* etc. In rupestribus aridis, prope Bath, Mainensium, *Gambell.* Newfoundland, *Cormack* (ex *herb. Lamb.* fide cel. *Tuckerman*). Primo vere floret.

The figure and analyses here given were principally made, in the spring and summer of the year 1845, from specimens of the living plant obligingly communicated to the Botanic Garden of Harvard University, by Gustavus Gilbert, Esq., of Plymouth.

This low and spreading shrub, with its evergreen heath-like foliage, blossoms at the same time as the Epigæa, in early spring. The staminate plants then present a very pretty appearance, each branch being crowned with a capitate cluster, of which the slender

tufted stamens, tipped with brown-purple anthers, are principally conspicuous, and are persistent for a considerable period. It then has the aspect of some Diosma, rather than of a Heath or a Crowberry. The fertile flowers are by no means showy, except when clusters are found which exhibit stamens as well as pistils, which is not unusual. In this case, however, few of the flowers are really perfect. For, when the pistil is well formed, the stamens are commonly more or less reduced, either by the suppression, partially or completely, of one cell of the anther, or by the reduction of one or more of the filaments to mere vestiges. Three cases of this sort, selected from a full series of such analyses, are represented in Figures 6, 7, and 8. The fertilized flowers are succeeded in the course of the summer by clusters of small and juiceless drupes, which, by the proliferous growth of the shoots of the season, now usually appear to be lateral; as is shown in the right-hand figure of the accompanying plate. The full generic character already given, the explanation of the plate, which comprises the more requisite analyses, very carefully drawn by Mr. Sprague, together with the ensuing historical and critical observations, render a further detailed description of the plant unnecessary.

Dr. Torrey, in the article above cited in which this plant was first made known, has recorded the history of its discovery, by the late Professor Solomon W. Conrad, near Pemberton Mills, about ten miles from Burlington, New Jersey, and subsequently by the late Mr. Rafinesque at Cedar Bridge, in Monmouth county of the same State; from which locality Dr. Torrey himself obtained a supply of living specimens. It has since been detected by Dr. Knieskern at other localities in the "Pine barrens" of New Jersey. Recognizing in this plant an interesting accession to the small family *Empetraceæ*, Dr. Torrey referred it, though with some hesi-

tation, to the genus Empetrum itself. His faithful description, although drawn from less perfect specimens than we now possess, leaves little to be added, except the account of the fruit, which was then unknown. He did not fail to notice its agreement in habit and some points of structure with the Empetrum album, *Linn.*, the Corema of Don.* Had the latter plant been known to him otherwise than by an imperfect and faulty description, the agreement would certainly have been more insisted on.

In the autumn of 1840, Mr. W. Gambell gave me good specimens of this plant, which he had gathered the preceding spring on the rocky banks of the Kennebec, in the neighbourhood of Bath, Maine. For the discovery of this station, I believe we are indebted, not to Mr. Nuttall directly, as has been stated,† but to his enterprising young friend and pupil just named. Previously to this, however, namely, in 1838 and 1839, the Plymouth locality had been brought to notice by Mr. Russell, Mr. Gilbert, Mr. Tuckerman, who identified it with the Empetrum Conradii of Torrey, and Mr. Oakes, by whom the ripe fruit was first detected.

Specimens having been communicated by Mr. Tuckerman to Dr. Klotzsch of Berlin, this botanist was led to study the plant, and to propose its establishment as a new genus, which he very appropriately dedicated to Mr. Tuckerman. In the detailed generic character of *Tuckermania* by Klotzsch, the nature of the fruit was first made known.‡ The seed, however, was not examined; its structure, and that of the embryo, have been left for me to sup-

* *Annals of the Lyceum of Nat. Hist. of New York, l. c.*, p. 86.

† *London Journal of Botany*, Vol. I., p. 445.

‡ "Fructus parvus, drupaceous, siccus, depresso-globosus, tri- abortu dipyrenus, pyrenis cartilagineis monospermis. Semen ?" *Klotzsch, in Erichs. Archiv., l. c.*, p. 250.

ply. The points in which the generic characters by Klotzsch differ from the detailed description by Torrey are few and slight, and, I may add, not invariably correct. The rank of the scarious envelopes of the flower, called by Torrey, with purposed ambiguity, the "scales of the perianth," and by Klotzsch distinguished into a "calyx triphyllus," and a "corolla diphylla," is of course a matter of opinion. But they cannot, except in an arbitrary manner, be divided into an outer and inner series; they are imbricated one over another, in the manner of the scales of a winter bud, which purpose they subserve; they vary in number from five to six or more, and the only difference is, that the inner are successively thinner and more hyaline, as in an ordinary bud. These have not the petaloid appearance or texture of the "petals" of Empetrum, which form apparently a true perigonium. It were perhaps best to consider the whole of them as equivalent to the "six imbricated scaly bracts" of Empetrum. However that may be, they are absolutely the same as the "calyx 3-phyllus; petala 3" of Corema, *Don*, that is, when actually six in number, which is not uncommonly the case. Klotzsch's character, "corolla (fœm.) diphylla," should therefore be *corolla 2–3-phylla*, when it would agree with Dr. Torrey's description, though in other terms. In describing the corolla of the sterile flowers, Klotzsch has unfortunately mistaken an occasional and plainly accidental deviation for the regular structure.* Although these inner scales do sometimes grow together more or less, in the manner exhibited at Fig. 4, yet this union is quite casual and variable, and obviously of no moment, except as it tends to show that these organs are not really petals. The stamens, though generally three, are often four, as Dr. Torrey had

* "Corolla (fl. masc.) tenuissime membranacea, cyathiformis, apice truncata et minutissime denticulata, longitudinaliter fissa, deinde diphylla." *Klotzsch, l. c.*

stated. The ovary is merely said to be three-celled by Klotzsch; and by Torrey, with closer correctness, 3–4-celled. It is sometimes, though rarely, five-celled, the divisions of the style varying in like manner; and, I may add, that these are quite irregular, and often (as in Corema) a little incised or two-toothed. Dr. Klotzsch's summary of the points in which his genus is held to differ from its nearest allies will be noticed presently.

On his return from Germany to England, in the summer of 1842, Mr. Tuckerman, learning that the name which Dr. Klotzsch gave to this genus had been already applied to a different plant by Mr. Nuttall,* embraced the opportunity that now offered to dedicate such an interesting New England plant to William Oakes, Esq.; a botanist whose name is "inseparably connected with the New England Flora" which he has done, and is doing, so much to illustrate. Mr. Tuckerman's article was published in the first volume of Hooker's *London Journal of Botany*, in the autumn of 1842. He was enabled to extend our knowledge of the geographical range of the plant, by detecting a specimen in the Lambertian herbarium, gathered in Newfoundland † by Mr. Cormack, which the late Professor Don had misnamed "Ceratiola ericoides." He also gave a good history of our knowledge of the plant up to that time; and repro-

* Tuckermania, *Nutt. in Trans. Amer. Phil. Soc.; Torr. and Gr. Fl. N. Amer.* 2, p. 355; a showy Californian Composita. Specimens likewise exist in the late Dr. Coulter's Californian collection.

† Dr. Torrey (in *Ann. Lyc., l. c.*), having noticed that Pylaie had included Empetrum rubrum in the enumeration of his Newfoundland collection, inquires whether this may not be his Empetrum Conradii. Now that Newfoundland specimens of the latter plant have been brought to light by Mr. Tuckerman, it becomes interesting to answer this inquiry. An examination of Pylaie's herbarium enables me to state that his "Empetrum rubrum ? L." is not E. Conradii, but is very like the Magellanic species.

duced Klotzsch's generic character, merely changing the name to *Oakesia.* This character was again repeated, soon after, by Hooker, accompanied by a figure of the plant, with some good analyses of the flowers, which, he remarks, do not so well accord with Dr. Klotzsch's description as could be wished.* Hooker has well represented the perianth or scales of the flower. He also detected an abortive pistil in one of the sterile flowers. The fruit was unknown to him, and, indeed, that possessed by Mr. Tuckerman and Dr. Klotzsch was said to be abortive.

Good fruit, however, was gathered by Mr. Oakes, and communicated both to Dr. Torrey and myself; it has also ripened in the Botanic Garden at Cambridge. The mature drupes are represented of the natural size in the right-hand figure of the accompanying plate; they are no larger than a pin's head, and have, even when fresh, only a thin coating of juiceless flesh. In the dry state, the cartilaginous pyrenæ may be made to separate by considerable pressure, when they incline to open by the ventral suture; but I believe the fruit is never spontaneously dehiscent. The erect seed, which fills the cell of each pyrena, has a taper embryo in the axis of fleshy albumen, of two thirds its length, the radicle being, of course, inferior, and the cotyledons very short.

In order rightly to estimate the value of the characters assigned to the genus Oakesia, it will be necessary to correct some errors which prevail respecting Empetrum itself. The late Professor Don, in drawing out the characters of the order Empetreæ, stated that the ovary rests on a fleshy disk;† which character is more strongly pre-

* *Icones Plantarum*, Vol. VI. (or II. new series), t. 531 (1843).

† "Ovarium . . . . . disco carnoso impositum." *Don, in Edinb. New Phil. Journal*, Vol. II., p. 62.

sented by Lindley, namely, "ovary seated in a fleshy disk,"* and has been copied by Endlicher into the description of each genus in the form of "Ovarium disco carnoso insidens."† But I can find *no disk whatever*, either in Empetrum nigrum or E. rubrum, or indeed in any other plant of the family. Another mistake, relating to the insertion of the seed and the pericarpic direction of the embryo, appears also to have originated with Professor Don. He characterized the seed in the whole order as erect or ascending (at least by implication), and the radicle of the embryo as inferior,—characters which have been adopted without scrutiny by succeeding systematic writers, but which, though true as respects Corema, Ceratiola, and Oakesia, are not applicable to Empetrum itself. The only correct representation of the insertion of the seed in Empetrum is that in the well known *Genera Plantarum Floræ Germaniæ* of the younger Nees von Esenbeck.‡ The seed in E. nigrum (as also in E. rubrum) is, in fact, suspended from the upper inner angle of the bony cell, just as the artist has represented in Fig. 19 of the plate in the work referred to. But in the longitudinal section of the seed, at Fig. 20, the artist has depicted the embryo with the radicle inferior, and the cotyledons next the hilum; or, in other words (the seed being anatropous), has made the *cotyledons*, instead of the radicle, *point to the micropyle!* which is of course an impossibility. Endlicher has cited the plate without correcting the incongruity, but, probably supposing that the mistake regarded the seed rather than the embryo, has rejected what was really correct in the

* *Nat. System*, ed. 2, p. 117, and *Vegetable Kingdom*, p. 285.

† *Genera Plantarum*, p. 1106.

‡ Even here the structure is misapprehended in the text; the drupe being called a berry, the pyrenæ, seeds, the hilum, an internal chalaza, &c. The correct view is suggested, however, in a parenthesis at the close.

figure, and adopted the error. But any botanist may readily satisfy himself, by examination, that the radicle in Empetrum lies next the hilum, and points to the apex of the fruit;* thus invalidating the character on which Don and Lindley rely for distinguishing the family from Euphorbiaceæ. Since the other genera of this truly natural group differ from Empetrum in really possessing an erect seed and an inferior radicle, I may remark, in passing, that we have here a case in point against the adoption of a rule recently laid down by M. Ad. Brongniart, namely, that the direction of the radicle is of much higher importance considered with respect to the pericarp than with respect to the hilum.†

The diagnosis of the genus Oakesia is stated by Klotzsch (I cite from the translation by Mr. Tuckerman) as follows: — "We find that *Empetrum* differs in having single axillary flowers supported by three bracts, a three-leaved corolla, a 6–9-celled ovary sunk in a fleshy disk, and a closely sessile radiately expanded 6–9-cleft stigma; that *Corema*, agreeing with this plant in the habit and inflorescence, is yet distinguished from it by the want of bracts, by a three-leaved corolla, an ovary sunk in a fleshy disk, and a radiately expanded six-cleft stigma supported by a short style; and that *Cera-*

* In no case have I found the embryo *eccentric*, as it is figured and described in the *Genera Fl. Germaniæ*, but always directly in the axis of the albumen, and with a slight curvature corresponding to that of the seed. Neither is it so long as there depicted; being scarcely more than two thirds the length of the albumen. It is in the work here referred to, that the compound pollen of Empetraceæ has alone been noticed; but it is most strikingly seen in Oakesia. It is singular, now that this group is so widely separated from Ericaceæ (to which Jussieu appended Empetrum), that it should, after all, be found to accord with the Heath tribe in this somewhat peculiar character.

† *Brongniart, Enumeration des Genres de Plantes cultiv. au Mus. Hist. Nat. Par.*, p. ix. (introduction).

tiola, approaching it in its two-leaved corolla, differs in having axillary flowers supported by four bracts, a two-leaved calyx, two stamens, a two-celled ovary sunk in a fleshy disk, and a radiately expanded six-cleft stigma, supported by a short style." *

I have already observed, that I can find no fleshy disk in Empetrum; and in the few flowers of Corema which I have been able to examine there is certainly no more trace of a disk than in Oakesia itself. There is usually a distinct though short style in Empetrum; but the scattered solitary flowers, proper petaloid perianth, 6–9-celled ovary, and, above all, the direction of the seed and embryo, which I have now pointed out, abundantly distinguish Empetrum from the plant in question. Ceratiola is distinguished by its scattered dimerous flowers and greatly developed laciniate stigmas; the latter, however, are two, deeply 2-parted, and incised, rather than a "stigma subsexfidum." But as respects Corema, I can confirm none of the distinctive marks that have been indicated. Where Dr. Klotzsch refers to the "want of bracts" in Corema, he has, I fear, misapprehended the phrase, "Calyx triphyllus membranaceus, basi nudus," of Don, who evidently refers to the want of *bracteolæ*, beyond the six which he regards as calyx and corolla.† In this respect, as well as in the texture and appearance of these envelopes, Corema and Oakesia are quite alike, except that the number in the latter is *sometimes* one fewer. The casual union of the innermost may surely be disregarded. The style and its branches are shorter in the Portuguese than in the American plant, but the differ-

* *London Journal of Botany*, *l. c.*, p. 446.

† If, on the other hand, Dr. Klotzsch refers to proper bracts, namely, the scales of the capitulum subtending each flower, these certainly are present in Corema, as well as Oakesia, though not so conspicuous, and are described by Don and Endlicher. In Oakesia they are rounded and pointless; in Corema, acuminate.

ence is inconsiderable; and, instead of a "stigma sexfidum" in the former, I have only met with a style three-cleft at the apex, the lobes thus answering to the cells of the ovary, and one or two of them often more or less two-cleft at the apex. The pilosity of the receptacle of the head of flowers in Corema is simply a continuation of the pubescence of the branches, &c., in which Corema differs from Oakesia, just as Empetrum rubrum does from E. nigrum. The habit of the two plants is very similar; although Corema alba, in its erect growth and slenderer leaves, has apparently more the aspect of our Ceratiola. I have not seen the ripe fruit of Corema, but if the drupes figured by Gærtner were full grown, they are little larger than in our plant, and the pulp is sparing. A difference in the amount merely of the sarcocarp can be of no generic consequence; but beyond this I know of no tangible character to distinguish Oakesia from Corema.

I have to regret, therefore, that such a poorly marked genus should have been dedicated to so excellent a botanist as my valued friend, Mr. Oakes. The accompanying plate was lettered and engraved before I had made the examinations which have led to this conclusion. In this view, I have perhaps been anticipated by my distinguished associate, Professor Torrey; for among my specimens I find one ticketed by him "*Empetrum* (*Corema*) *Conradii*."

With our present knowledge, the diagnoses of the three genera of Empetraceæ must, I think, stand as follows: —

1. Empetrum, *Tourn.*, *Linn.* (excl. sp.)

Flores in axillis foliorum solitarii, sparsi, triandri. Perigonium proprium petaloideum. Stylus brevissimus: stigma 6–9-radiatum. Drupa baccata 6–9-pyrena. Semina pendula; radicula supera! — E. nigrum, *Linn.* E. rubrum, *Vahl.*

2. Ceratiola, *Michx.*

Flores in axillis foliorum solitarii vel pauci aggregati, diandri. Perigonium proprium nullum. Stylus crassus: stigma foliaceum circa 4-partitum, lobis inciso-pinnatifidis. Drupa dipyrena. Semina erecta: radicula infera. — C. ericoides, *Michx.*

3. Corema, *Don.* (Tuckermania, *Kl.* Oakesia, *Tuckerm.*)

Flores capitati, bracteis squamæformibus suffulti. Perigonium proprium nullum. Stylus gracilis, 3- (nunc 4–5-) fidus, lobis angustis. Drupa sæpius tripyrena, parva. Semina erecta: radicula infera. — C. alba, *Don.* C. Conradii, *Torrey & Gray.*

Tab. I. ***Oakesia*** (potius ***Corema***) ***Conradii***, staminate, pistillate, and fruiting specimens, of the natural size. ***Fig.*** 1. Leaves, magnified; view of the upper and under sides. ***Fig.*** 2. Capitulum of the sterile flowers, enlarged. ***Fig.*** 3. Magnified staminate flower, with the three inner enveloping scales (corolla, of ***Klotzsch***) spread open (the stamens in this instance four in number). ***Fig.*** 4. Magnified staminate flower, with the two innermost scales united on one side. ***Fig.*** 5. Pollen (consisting of four combined grains), highly magnified. ***Fig.*** 6. A magnified subhermaphrodite flower, with its scales spread open, showing an abortive pistil, and the one-celled anthers; in one of the stamens there is the rudiment of the second anther-cell. ***Fig.*** 7. Enlarged hermaphrodite flower, with one dimidiate stamen, and two rudimentary filaments; the pistil normal. ***Fig.*** 8. Hermaphrodite flower, the stamens all with dimidiate anthers. ***Fig.*** 9. Capitulum of fertile flowers, enlarged. ***Fig.*** 10. Magnified pistillate flower, with the inner scales. ***Fig.*** 11. Magnified pistillate flower, with a four-cleft style, and the scales spread open. ***Fig.*** 12. A drupe, cut across, magnified. ***Fig.*** 13. One of the detached pyrenæ, cut across, and more magnified. ***Fig.*** 14. Vertical section of a drupe, magnified; the section passing through one pyrena, seed, and embryo, and leaving the other pyrena entire. ***Fig.*** 15. The embryo detached, and more magnified.

SCHWEINITZIA ODORATA, *Ell.*

TAB. II.

SCHWEINITZIA, *Ell. Sk. Bot. S. Car. & Georg.*, 1. *p.* 478.

Calyx quinquesepalus, marcescens; sepalis carinato-concavis, basi vix bigibbosis. Corolla campanulata, persistens, breviter quinqueloba, carnosula, basi quinquegibbosa; lobis ovatis patentibus. Stamina 10, hypogyna: filamenta subulato-filiformia, glabra: antheræ juxta apicem introrsim affixæ (in alabastro non reversæ), didymæ, biloculares, loculis sacculiformibus vertice foramine amplissimo hiantibus. Pollen simplex. Ovarium subglobosum, basi disco hypogyno decemcrenato, dentibus staminibus alternantibus, cinctum, quinqueloculare, loculis multiovulatis: stylus brevis, crassus: stigma pentagonum, leviter quinquecrenatum, umbilicatum. Capsula . . . . .

Rhizophytum hypopythoideum, humile, badium, glaberrimum; floribus consimilibus spicatis, odorem Violæ spirantibus: corolla carnea.

S. ODORATA, *Ell., l. c.; Nutt. Gen.* 2. *p.* 270 (*Suppl.*); *DC. Prodr.* 7. *p.* 780.

S. Caroliniana, *Don, Gen. Syst.* 3. *p.* 867.
Monotropsis odorata, *Schwein. in Ell., l. c.*

HAB. In sylvis, humi pingui, frondibus delapsis quan-

doque latens, Carolinæ Septentrionalis juxta Salem, ubi detexit beat. *Schweinitz;* necnon sub scopulo "Table Mountain" dicto cl. *Sullivant* mecum legit. Prope urbem Baltimore in Marylandia, cl. *Griffith.* Primo vere floret.

Very few phanerogamous plants of the United States are so little known as the Schweinitzia. Excepting the discoverer, whose name it bears, no botanist had met with it until it was gathered in the neighbourhood of Baltimore a few years ago by Dr. Griffith. In the autumn of 1843, Mr. Sullivant and myself were so fortunate as to find a few specimens at the base of Table Mountain, North Carolina.* Our specimens were growing in a cluster from the roots of Galax, upon which they appeared to be parasitic. As we removed the whole mass, with the hope of securing the plant in a living state, we did not examine the mode of attachment, which is so difficult to make out in other Monotropeæ, and which is so doubtful in the case of Monotropa itself.† The specimens already (in September) bore well formed flower-buds, some of them nearly full sized and ready for expansion in the spring. From them were taken the specimens represented in the right and left hand figures of the accompanying plate. The central figure, from a specimen gathered by Dr. Griffith, represents the plant soon after flowering; when the short spike, which was before drooping, becomes erect.

* *Amer. Journal of Science and Arts*, New Series, Vol. I., p. 18.

† The development of Monotropa, and its mode of parasitism, if there be any, is a subject upon which a series of original observations is greatly needed, and which would well reward the attention of a careful observer.

Several such simple stems spring in a cluster, from a coralloid-fibrous and matted root, to the height of two to four inches. They are purplish in color, and are thickly beset with the rather fleshy brownish scales which take the place of foliage; these are ovate, acute, one-nerved, spirally alternate, about three lines in length; the upper becoming rather larger and more crowded, forming the bracts of the spike, and partly enveloping the blossoms. The flowers, usually six or eight in number, are borne on very short pedicels, and are subtended by a pair of opposite bracteoles, which resemble the bracts, and are intermediate in size and shape between them and the sepals. The calyx consists of five imbricative sepals, as long as the corolla; these are scarious in texture in the dried state, ovate-oblong or lanceolate-oblong, acute or acutish, more or less concave, and slightly gibbous at the very base. The corolla is about one fourth of an inch long, thickish, of a firm fleshy texture, imbricated in æstivation, and with five rather strong gibbosities at the base, corresponding with the lobes. The stamens are a little shorter than the corolla; the anthers are nearly as broad as long; the two short saccate cells are somewhat enlarged downwards, and are united by their contiguous faces without any connective; they are attached to the filament by a point at or near their summit on the outside, so that they are introrse. They are not retroverted before anthesis, like those of Pyrola,* but are turned inwards from the first. I notice, however, that, in the young

* By almost every writer, from Wahlenberg and Don to Koch, De Candolle, and Endlicher, the anthers of Pyrola are said to open by *basal* pores, and to be *inverted* during flowering. The pores, are, however, really *apical*, as in Ericaceæ proper; the anthers are *retroverted* in the flower-bud, as is common in the order, and resume the truly normal position soon after the flower opens. The correct view was adopted by Dr. Torrey, in his *Flora of the Northern and Middle States*, p. 432.

flower-bud, the anther is usually turned nearly at a right angle with the filament, so that the points which mark the apical foramina are lateral. By the time the corolla expands, the anthers have assumed their normal position, and appear pendent from the filament, as is shown in Fig. 7 and Fig. 8. The open pores, if they may be so called, through which the pollen is discharged, are so large, that, like the mouth of a sac or purse, they now occupy the whole summit of the cell. At first, each anther-cell is divided by a transverse septum, the vestiges of which are sometimes distinctly visible after the pollen is discharged. The pollen is simple, as in all other Monotropeæ. But in examining, with the higher powers of the microscope, the pollen taken from autumn flower-buds, I found that what before appeared like simple grains consisted of mother-cells, each containing two, three, or commonly four, distinct pollen-grains. These are shown in Fig. 9, under an amplification of about three hundred diameters. The five-sided umbilicate stigma is apparently composed of five erect and connate lobes. A section of the ovary appears very much as in Monotropa. The thick placental axis projects two lobes into each cell, which are thickly covered with innumerable minute ovules. An apparently fertilized ovule, or growing seed, as it appears when strongly magnified, is given at Fig. 12. The mature seeds and the fruit are unknown.

The late Mr. Von Schweinitz, the distinguished botanist who discovered this remarkable plant, sent to Mr. Elliott the brief description published in the work before cited, which is excellent, as far as it goes; — Mr. Elliott at the same time proposing to change the name *Monotropsis*, given by Schweinitz, to *Schweinitzia*, in honor of the discoverer. In the supplement to his *Genera of North American Plants*, Mr. Nuttall has somewhat altered, but not

improved, the character of the genus. The anthers, according to Nuttall, are "adnate to the filaments, one-celled, opening from the inverted base by two naked pores." The anthers are, however, plainly two-celled at every stage, and their orifices were probably assumed to be basal on account of their obvious resemblance to those of Pyrola, which are (wrongly) so described by Nuttall and most other authors. These characters were copied by Don,* and the latter has been adopted by Endlicher,† and, on Nuttall's authority, by De Candolle, who, although he possessed a specimen of the plant, appears not to have investigated the structure of the flower. Sprengel cites Monotropsis as a synonym under Monotropa.‡

The small group of Monotropeæ may be said to consist of Ericineæ or Pyroleæ without green foliage, and with the mode of life and the aspect of Orobanchaceæ. They have apparently no other combining character. The anthers of Schweinitzia open by pores; those of Pterospora open longitudinally, though they are otherwise, as well as the corolla, much the same as in Andromeda. The anthers of Hypopitys open by a continuous transverse line into two very unequal valves; those of Monotropa, which stand transversely on the apex of the filament, open by two terminal transverse chinks. Lindley gives indeed another character, namely, that "there is a difference in the position of the embryo, that organ being at the apex of the albumen in Monotropeæ," but at the base in other Ericaceæ. § But the embryo of Monotropeæ is entirely unknown,

* *Gen. Syst. Gard. & Bot.*, Vol. III., p. 867. The name is here inadvertently changed to "S. Caroliniana, *Ell.*"

† *Genera Plantarum*, p. 761.

‡ *Genera Plantarum*, Vol. I., p. 347.

§ *Lindley, Introd. Nat. Syst.*, ed. 2, p. 219, and *Veg. Kingdom*, p. 452.

except as to Pterospora; and even with regard to this the observation greatly needs verification.

Tab. II. *Schweinitzia odorata*, of the natural size. *Fig*. 1. A detached flower, enlarged. *Fig*. 2. A flower, enlarged, with the sepals spread open. *Fig*. 3. Unexpanded corolla, from an autumnal flower-bud. *Figs*. 4, 5. Two sepals of the same. *Fig*. 6. Corolla laid open. *Fig*. 7. Magnified flower, the calyx and corolla removed. *Fig*. 8. A stamen, more magnified. *Fig*. 9. Pollen from young anthers, highly magnified; the 2–4 grains still inclosed in mother-cells. *Fig*. 10. Separate simple pollen-grains, equally magnified. *Fig*. 11. Transverse section of the ovary. *Fig*. 12. A fertilized ovule, highly magnified.

OBOLARIA VIRGINICA, *Linn.*

TAB. III.

OBOLARIA, *Linn. Gen. no.* 778.

Calyx diphyllus ; sepala foliiformia, spathulato-oblonga, patentia, in floribus axillaribus lateralia. Corolla tubuloso-campanulata, marcescens, regularis, ad medium æqualiter quadrifida ; lobis ovali-oblongis, demum oblongo-spathulatis, parce denticulatis ; æstivatione imbricativa. Stamina 4, in sinubus corollæ inserta : filamenta brevia, æqualia : antheræ subglobosæ nunc sagittiformes, loculis longitudinaliter dehiscentibus : pollen globosum, membrana tenuissima lævissima. Ovarium ovoideum, stylo brevi stigmatibusque 2 ovalibus subplanis persistentibus coronatum, uniloculare, etsi processibus endocarpii semi-bi – tri-loculare, vel sæpius cruciatim semi-quadriloculare, parietibus undique ovuliferis. Ovula numerosissima, anatropa. Capsula polysperma, membranacea, septicida ? Semina immatura testa laxa cellulosa donata, nucleum parvum includentia.

Herba spithamæa, glaberrima, carnosula ; radice perenni, ramosa, e fibris crassiusculis ; caule subsimplici tetragono ; foliis oppositis, sessilibus, obovato-cuneatis, sæpe retusis, integerrimis, leviter quinque – septem-nervatis, livido-viridibus et purpureo tinctis, plerisque versus apicem caulis approximatis ; imis squamæformibus vel

obsoletis, quandoque alternis; inflorescentia centrifuga, floribus terminalibus axillaribusque solitariis tribusve, ad apicem pedunculi brevis inter bracteas foliiformes sessilibus. Corolla albida, sæpe lilacino vel purpureo tincta.

O. Virginica, *Linn. Spec.* 2. *p.* 632 (*Gronov. Fl. Virg.*, *ed.* 2. *p.* 95); *Nutt. Gen.* 1. *p.* 103; *Ell. Sk.* 2. *p.* 134; *Darlingt. Fl. Cest.*, *ed.* 1. *p.* 21, *t.* 2; *Barton, Fl. N. Amer.* 3. *t.* 90.

Obularia, *Linn. Hort. Cliff.*, *p.* 323.

Orobanche Virginiana, radice coralloide, summo caule foliis subrotundis. *Moris. Hist.*, 3. *p.* 504, *t.* 16, *f.* 23.

Orobanche Virginiana, radice fibrosa, etc., *Pluk. Alm.*, *t.* 209, *f.* 6.

Anonymos humilis, Aprili florens, floribus pallide rubentibus, etc., *Clayt. Fl. Virg.*, *l. c.*

Schultzia obolarioides, *Raf. in N. Y. Med. Repos.*, 2. *hex.* 5. *p.* 350?

Hab. In solo pingui sylvarum Novæ Cæsareæ, Pennsylvaniæ, Ohionis, Virginiæ, usque ad Carolinam Australem et Texas, rarius; primo vere florens.

This plant has been several times figured, but never with the requisite analyses. On this account, and because its remarkable peculiarities have remained unnoticed, and its place in the natural system doubtful, I am induced to attempt its illustration.

Linnæus founded the genus upon specimens sent from Virginia by Clayton to Gronovius, transferring to it the name formerly proposed by Siëgesbeck for Linnæa.* He did not characterize it well

* "Obularia dicta fuit ob convenientiam foliorum cum figura obulorum, præsertim Ruthenicorum." *Linn. Hort. Cliff.*, p. 323.

in the *Genera Plantarum*, where the corolla is said to be unequally four-cleft, and the stamens didynamous. The genus was accordingly placed in the class Didynamia, next to Orobanche. The two-leaved calyx, if such it be, Linnæus considered rather as a pair of bracts. From the expression, "Capsula . . . . bivalvis, dissepimento opposito," it may be inferred that he took the ovary to be two-celled. Nevertheless, Jussieu,* who professes to have derived his generic character from Linnæus, ascribes to the plant a one-celled capsule. He includes the genus in that section of his order Pediculares (III. Genera Pedicularibus affinia), which answers to his Orobancheæ, subsequently so called.† Persoon briefly remarks, that Obolaria is quite different from Orobanche in habit, though agreeing with it as to the flower.‡ By some inadvertence, he has attributed to it a "calyx quinquefidus."

To Dr. Darlington belongs the credit of having first shown that the corolla of Obolaria was regular and the stamens equal, — points which he indicated to Professor Barton, and afterwards to Mr. Nuttall.§ In the *Genera of North American Plants*, Mr. Nuttall, coinciding in this view, describes the stamens as equal, and places the genus in the Linnæan class Tetrandria. He describes the capsule simply as "one-celled, two-valved, many-seeded; seeds minute." Premising that the plant is bitter (which it certainly is, though not strongly so), and probably tonic, Nuttall makes the important statement, that the genus "distinctly appertains to the natural order *Gentianeæ* of Jussieu." Dr. W. P. C. Barton, who, in the work

* *Genera Plantarum*, p. 101.

† *Ann. Mus.*, Vol. XII., p. 445.

‡ *Synopsis Plantarum*, Vol. II., p. 182.

§ *Florula Cestrica*, ed. 1, p. 21, where there is a good description and a pretty good figure of the plant in question, which is placed in the artificial class Tetrandria.

above cited, has given a tolerable figure of the plant, follows Nuttall in referring the genus to Gentianeæ. Sprengel appears to be the only succeeding author who has adopted this view.* Elliott, although he has introduced the genus under the class Didynamia, states that the plant, "from the structure of the corolla and the insertion of the stamens, certainly belongs to the class Tetrandria." † He makes no remark respecting its natural affinity. But in his account we meet with the earliest, and indeed the only, indication of any peculiarity in the structure of the ovary. He describes the capsule as "four-celled? or perhaps one-celled with the rudiments of partitions."

The late Professor Don,‡ in a revision of the order Orobancheæ, appends to it a tribe *Obolariæ*, comprising Obolaria and the (totally unlike) genus Tozzia, which are merely said to differ from Orobancheæ proper in being terrestrial instead of parasitical. Bartling § also enumerates the genus Obolaria under Orobancheæ. So, likewise, does Lindley, both in his *Introduction to the Natural System*, and in the recent *Vegetable Kingdom*. Endlicher, on the other hand, has placed the genus among the "Scrophularineis affinia," remarking that it appears not to belong to the Orobancheæ, but may perhaps be referable to the Gentianeæ.|| The structure of the ovary and of the capsule are described by Endlicher in somewhat incongruous terms. The *ovary* is said to be *one-celled, with two parietal placentæ*, while the *capsule* is said to be *two-celled, two-valved, the valves placentiferous in the middle.* Neither of these

* *Genera Plantarum*, Vol. I., p. 110.

† *Sketch of the Botany of South Carolina and Georgia*, Vol. II., p. 134.

‡ In *Edinb. Phil. Journ.*, Vol. XIX., p. 113.

§ *Ordines Naturales*, p. 174.

|| *Genera Plantarum*, p. 695.

statements accords with our observation. The dehiscence of the capsule, however, I have not seen; but I can scarcely doubt that it is septicidal, or, in other words, that the carpels separate from their margins. Meisner* has followed Endlicher in appending Obolaria to the order Scrophulariaceæ. Grisebach† has neither included it in the order Gentianeæ, nor mentioned it among the genera which have been referred to that order; the remark by Nuttall and its adoption by Sprengel having probably been overlooked by him.

It is manifest, from the foregoing summary of what is on record respecting Obolaria, that its affinities are still unsettled, and that the peculiar structure of the ovary has not been made known. This peculiarity, which I have endeavoured to express in the detailed generic character given above, and in the accompanying analyses, was first noticed in the living plant by Professor Torrey and myself, in the spring of the year 1843.

A view of the transverse section of the ovary, considerably enlarged, is given at Figure 11 of the accompanying plate. The parietes of the ovary consist, first, of a thin exterior coat, composed of compressed cellular tissue alone, and quite similar to the skin or epidermis, which readily peels from the stem, &c. This coat is but slightly coherent with the parts subjacent, except at the two longitudinal lines, which, alternating with the lobes of the stigma, evidently correspond to the margins of the carpels, and doubtless with the lines of dehiscence at maturity. The outer coat does not follow the introflexions of the interior, or endocarpic, por-

* *Plantæ Vasculares*, p. 313.

† *Genera et Species Gentianearum, etc.*, 1839, and Gentianaceæ *in DC. Prodr.*, Vol. IX.

tion; and the intervening space is partially filled by a little very loose and filmy cellular tissue. The inner portion of the parietes is much thicker and more fleshy than the outer; it commonly presents four equidistant projections or folds, which partially divide the cavity in a cruciate manner; but occasionally one of these, or two opposite ones, are partially or altogether wanting. These four placentiform folds may be directly compared with the four nearly equidistant placentæ of *Anoplanthus* (*Orobanche*) *uniflorus*, with which they agree in position; that is, two of them are borne on the face of each carpel, about half way between its edges (marked by the line alternating with the stigmas) and the axis (where the midrib is represented by a slender line or cord of vessels, shown in the middle of Fig. 12, which may be traced upwards through the style to the stigma); so that they might be taken for submarginal half-placentæ. But here we find a further peculiarity in Obolaria, namely, that not merely these placenta-like processes, but the whole lining of the cell, is equally and uniformly ovuliferous! Of this, no parallel instance is known, I believe, in a unilocular compound ovary, although it occurs in a few plants with apocarpous ovaries, and in one small family (Nymphæaceæ) with a compound multilocular fruit; but to none of these does Obolaria exhibit any other points of similarity.

The want of much cohesion, except at the sutures, between what I have called the outer and the inner parietes of the ovary naturally suggests another possible explanation of the anomalous placentation of Obolaria; namely, that the inner ovuliferous portion may consist of a pair of concave placentæ, completely lining the ovary, much as in Hydrophyllum, but perfectly united where their edges come in contact, and ovuliferous throughout their whole sinuously biplicate inner face. But no trace of such union can be

detected at those sinuses which correspond with the axis of each carpel; and besides, this same endocarpic portion certainly makes up a part of the thickness of the style, as well as of the walls of the ovary.

Some points concerning the *position* of the flowers and their parts deserve notice. The axillary flowers are often solitary, when the short peduncle is bractless; otherwise they are three in a cluster or cymule; the two lateral being sessile, or nearly so, close at the base of the terminal, each arising from the axil of a bract resembling the sepals, or, indeed, the leaves. When the flower is solitary, the sepals (as we are obliged to term them) are uniformly lateral, as in the diagram, Fig. 6. Where the lateral axis bears three flowers, these are commonly disposed as is represented in the diagram, Fig. 1; that is, the two additional flowers are placed right and left, having, of course, the same relation to the central flower which that, when solitary, has to the main axis. The sepals of the central flower in this case are not *lateral*, but *anterior* and *posterior*, namely, one next the axis, the other next the bracteal leaf. It is obvious, therefore, that the same organs which stand for the calyx of the solitary flower, Fig. 6, form the bracts of the three-flowered cluster in Fig. 1; the calyx of the central flower in this latter case being just the next pair of leaves of the branch, decussating with the first pair, and therefore necessarily standing fore and aft, as respects the primary axis and cauline leaf. This gives some apparent confirmation to the Linnæan view, that what is called the *calyx* of Obolaria is no part of the flower, but rather a pair of bracts. The three flowers of the axillary clusters are not always thus disposed in a line at right angles (or nearly so) with that passing through the stem and cauline leaf. This is the prevalent, but not the uniform, mode. Dr. Torrey called my attention to the fact, that not unfrequently one or more of the clusters stand

in the opposite plane, the bracts being *anterior* and *posterior*, and the three flowers consequently occupying the line that passes through the cauline leaf and the main stem. An instance of the sort furnished the diagram, Fig. 2.

The position of the two constituent carpels of the ovary to the axis, and to the sepals, may be next considered. In the solitary axillary flower, the lobes of the stigma, and consequently the carpels, are commonly right and left, and parallel with the sepals, as in the diagram, Fig. 6, where the two oval figures placed in the centre represent the lobes of the stigma, and the two outer lateral lines, the sepals. Yet, in some cases, I have found the stigmas placed anterior and posterior, the two sepals remaining lateral, and therefore *alternate* with the sepals, instead of *opposed* to them, as is usual in this plant. This remark is equally applicable to the lateral flowers of the cluster of three. Although the stigmas are generally opposed to the sepals, and consequently lateral as respects the secondary bract, as in both diagrams, Figs. 1 and 2, yet in about three cases out of thirteen the stigmas alternate with the sepals, and are therefore opposed to the secondary bract and axis, that is, are anterior and posterior.* This prevalent opposition of the carpels to the sepals (with which they happen in this case to agree in number), so contrary to the general rule in Dicotyledones,† might be held to give additional probability to the idea that what are here called sepals are really bracts, — a view taken by Linnæus, doubtless on account of their close resemblance to the proper leaves of the plant, but which may also be maintained, as already intimated,

* In one cluster, the stigmas of one of the lateral flowers were seen to be anterior and posterior, while those of the other flower were right and left.

† *R. Brown*, *Observ. Pl. Oudney*, pp. 33, 38.

from the relation borne by what are called the sepals of the solitary flower to the bracts of the cluster, as well as from their want of agreement in number with the divisions of the corolla. But, on the other hand, the Gentian family, with which Obolaria is to be particularly compared, presents one of these same exceptional cases; their carpels being commonly (although, as in Obolaria itself, not uniformly) right and left of the axis, and consequently opposite the lateral sepals.

It is now evident, that the only natural orders to which Obolaria has any obvious relationship are those two to which it has been variously referred, namely, Gentianaceæ and Orobanchaceæ. The singular introflexions or processes analogous to the double (or rather separated) placentæ of some Orobanchaceæ would seem to favor its alliance with that order, in which, perhaps, the distribution of the ovules over the whole surface of the cell might the rather be expected. The (commonly) lateral position of the carpels would favor the association of Obolaria with Orobanchaceæ as much as with Gentianaceæ, if Lindley and Endlicher have correctly attributed this character to the former order. But against this is the much higher authority of Brown, who believes the carpels to be anterior and posterior in Orobancheæ.* The weight of this character, therefore, falls in favor of Gentianaceæ. The regular corolla, equal and isomerous stamens, and opposite leaves, are also points of difference from Orobanchaceæ, and of agreement with Gentianaceæ; to which may be added the green foliage and terrestrial growth, which would be altogether anomalous in the former family (although, on the other hand, one Gentianaceous genus is parasitic). The only point essentially at variance

* *Plantæ Javan. Rariores*, p. 112, note. — The carpels are certainly anterior and posterior in *Epiphegus*.

with the admitted character of Gentianaceæ is, unfortunately, one which is placed in the foremost rank by Grisebach, namely, the æstivation of the corolla. In Obolaria, the lobes of the corolla are *imbricated* in the bud, instead of convolute, as in the true Gentianaceæ, or induplicate, as in the Menyantheæ.* On this account, it might be proper to consider the genus as the representative of a third group, of equal rank with the Menyantheæ; and in this form it will accordingly be appended to the order Gentianaceæ, in the forthcoming portion of the *Flora of North America*, by Dr. Torrey and myself.

*** One or two mistakes have been committed in the analyses on the accompanying plate, which were not observed in time for correction. In Fig. 3, the leaves of the calyx are wrongly represented as decidedly distant from the base of the corolla, while, in fact, there is no such manifest interval. In Fig. 4, the sinuses of the corolla (laid open) should be of equal depth, and should extend to the insertion of the stamens; the filaments, moreover, are rather too short.

TAB. III. *Obolaria Virginica*, of the natural size. *Fig.* 1. Diagram illustrating the ordinary disposition, &c., of the three flowers of the axillary cluster. *Fig.* 2. Diagram of the *occasional* disposition of the same. In both, the lower crescentic line represents a section of the subtending leaf; the upper circular one, a section of the axis; the outer pair of the smaller crescentic

* Perhaps there is a tendency at present to consider the characters drawn from æstivation as more absolute and constant than they really are. Exceptional cases, as well as variations in the same species, will be found by no means uncommon. For example, although the æstivation of the petals is deemed to be universally convolute or twisted in Geranium and its allies, yet they are sometimes regularly *imbricated* in Geranium maculatum, or, in a greater number of cases, while four of the petals are convolute, the exterior one is wrapped around the others in the bud. I have also observed this anomaly in G. Robertianum, G. sanguineum, and G. collinum. So, likewise, the æstivation of the petals of Boykinia aconitifolia, *Nutt.*, is convolute, or perhaps sometimes convolute with the outer petal imbricative, while in other true Saxifrageæ the æstivation is regularly imbricated.

lines stands for the bracts of the cluster; the others are the sepals of the respective flowers; the circles they subtend stand for the corolla; the figures in their centre denote the position of the lobes of the stigma. *Fig.* 6. Diagram of the solitary axillary flower, and the æstivation of its corolla; the bract, axis, sepals, and lobes of the stigma are represented as in the foregoing; the series next within the sepals illustrates the æstivation of the corolla. *Fig.* 3. A separated solitary axillary flower, with its subtending bracteal leaf. *Fig.* 4. The corolla laid open, enlarged (corrected as above). *Fig.* 5. A stamen, more magnified. *Fig.* 8. The pistil magnified. *Fig.* 9. Apex of the style, with the stigmas, highly magnified. *Fig.* 10. A fertilized ovule, highly magnified. *Fig.* 11. The fructified pistil, with a cross-section of the ovary, showing the relation of the lobes of the stigma to the introflexed processes of the parietes, and the attachment of the ovules to the whole face of the cell. *Fig.* 7. Diagram of the same; the two oval approximate lines above denote the lobes of the stigma; the two minute circles placed right and left within the thickness of the walls of the ovary stand at the middle of the carpels; the introflexed lines at right angles with these indicate their margins or sutures. *Fig.* 12. One of the carpels or valves, separated through the sutures, style, and stigma, and spread open, the ovules having been removed.

GAILLARDIA AMBLYODON, *Gay*.

TAB. IV.

G. AMBLYODON : annua; caule ramisque diffusis hirtellis; foliis oblongis basi subauriculata sessilibus supra medium denticulatis serratisve, inferioribus subspathulatis; squamis involucri linearibus setaceo-acuminatis hispido-ciliatis tri–quadriseriatis conformibus basi callosa longiuscule coarctatis, mediis longioribus; ligulis (croceo-flammeis) **12–14** confertis; dentibus corollæ disci ovatis obtusis; fimbrillis receptaculi setiformibus crebris achenium parum superantibus; pappo radii exaristato!

G. amblyodon, *Gay, in Ann. Sci. Nat.* (*ser.* 2), 11. *p.* 57; *Torr. & Gray, Fl. N. Amer.* 2. *p.* 367; *Engelm. & Gray, Pl. Lindheim., no.* 104.

HAB. In arenosis provinciæ Texas, ubi collegerunt *Drummond, Lindheimer, Wright.* Floret ineunte æstate; in horto usque ad ultimum autumnum.

This species, without doubt the most showy of the genus, was first raised in the Cambridge Botanic Garden in the summer of 1845, from seeds sent from Texas by that assiduous collector, Mr. Lindheimer. It ripened seeds freely, from which the species is again cultivated the present season.

The plant grows after the manner of G. pulchella and G. picta, but is ranker, branching freely, forming ample clumps, two to three feet in height, and producing a succession of blossoms until it is

arrested by frost. The foliage is of a lighter hue than is represented in the engraving. The leaves are rather thick and fleshy, clothed with a minute and inconspicuous close pubescence; and the midrib beneath is sparingly fringed with bristly hairs similar to those which beset the stem, branches, and involucre. The capitulum, with the expanded rays, is fully two inches in diameter. The callous bases of the scales of the involucre are more strongly coarctate than in any other species. The spreading foliaceous part of the scales is usually very narrow, but in some spontaneous specimens the exterior are more or less dilated. The rays are closely set, cuneate-oblong in shape, three-lobed at the apex merely; their upper surface is of a deep cinnabar color, verging to orange towards the tips, especially in fading, but gradually deepening to red-brown next the base; the lower surface is browner than the upper. The tips of the exterior disk-corollas are very deep brown-purple, as are also the exserted filiform lobes of the style; while the central flowers are generally yellow. The disk-flowers persist in fruit, when they are quite showy, having much the appearance of a Scabious. The pappus consists of six to eight scarious and chaff-like ovate-lanceolate scales; those of the disk produced into awns, about the length of the corolla, as in the other species of the genus, while those of the ray-flowers are remarkable for being awnless. The specific name was chosen by M. Gay to express this peculiarity.

Tab. IV. *Gaillardia amblyodon;* branch of the natural size. *Fig.* 1. Ray-flower; the involucellate villous tuft at the base of the ovary spread open. *Fig.* 2. Disk-flower. *Fig.* 3. Capitulum, with the flowers removed, to show the acicular fimbrillæ of the receptacle. *Fig.* 4. Two of the fimbrillæ detached. *Fig.* 5. Achenium from the disk, with the pappus. All but Fig. 3 more or less magnified.

BRAZORIA TRUNCATA, *Engelm. & Gray.*

TAB. V.

BRAZORIA, *Engelm. & Gray, Pl. Lindheimerianæ, p.* 47.

Calyx late campanulatus, bilabiatus (labio superiore breviter tri- inferiore bilobo), per anthesin inflatus, fructifer auctus, membranaceus, reticulato-venosus, antice planiusculus, postice gibbosus, e surrectione labii inferioris clausus. Corolla tubo longe exserto, fauce inflata; limbi bilabiati labio superiore erecto, subgaleato, apice bilobo vel integro; inferiore tripartito, lobis patentibus vel recurvis rotundatis. Stamina 4, sub labio superiore adscendentia, manifeste didynama: filamenta supra medium corollæ adnata, ubi pilosa, inferioribus elatioribus: antheræ per paria approximatæ, biloculares, loculis distinctis divaricantibus ad rimam plus minusve ciliatis. Stylus glaber, apice subæqualiter bifidus, lobis subulatis. Achenia sicca.

Herbæ annuæ Texanæ, erectæ, Physostegiæ facie; foliis sessilibus oblongis denticulatis; floribus in spicis strictis quadrifariam congestis; corolla rosea, fauce albida vel luteola, purpureo guttata.

§ 1. Eubrazoria. Calycis lobi latissimi, subæquales, truncati. Corollæ majusculæ faux infra lobum anticum intrusa, quodammodo palatum efficiente. Achenia triangulata, pubera.

B. TRUNCATA: caule pubescente; spica densa; calyce bracteam ovatam æquante basi hirta, lobis brevissimis dilatatis labii superioris mucronulatis, inferioris eroso-denticulatis; labio corollæ ad faucem postice villosæ superiore breviter bilobo, inferiore subæqualiter tripartito, lobis reflexis apice bifidis emarginatisve, omnibus crenulato-erosis.

B. truncata, *Engelm. & Gray, l. c., no.* 287 (excl. syn. *Hook. Bot. Mag.*).
Physostegia truncata, *Benth. Lab., p.* 505, non *Hook.*

HAB. In provincia Texas (***Berlandier, Drummond, Wright***), præsertim secundum fluvium ***Brazos*** dictum (unde nomen genericum), in campis arenosis, formiceta derelicta diligens, ex ***Lindheimer***. Floret æstate.

This plant was first gathered by Berlandier, who communicated to Sir William Hooker the "very indifferent specimens" from which Bentham described it, in his excellent monograph of the family, under the name of Physostegia truncata. Had he possessed fruiting specimens, he would scarcely have joined to Physostegia a plant so distinct in its floral characters, however similar in aspect. Good specimens were afterwards collected by Drummond, who, "in 1833 and 1834, found it abundantly about San Felipe de Austin, and communicated specimens and seeds to Europe."* They were distributed under No. 274 of his third Texan collection, mixed, however, with those of a different species. It was from seeds of this last species that the specimens were raised which Hooker figured and described in the *Botanical Magazine* (t. 3494), mistaking

* Hooker, *Bot. Mag.*, sub. t. 3494.

it for the real Physostegia truncata of Bentham, and altering the specific character to make it accord with the plant before him.

These two species were subsequently gathered by Lindheimer, and distributed as No. 286 and No. 287 of his collection for 1844.* So numerous are their points of difference, that Dr. Engelmann, who had noticed them with his usual accuracy, proposed to consider the two as the types of distinct genera. I preferred, however, to combine them, in view of their entire agreement in habit, and in the mode in which the enlarged and gibbous fructiferous calyx is closed by the appression of the lower lip, notwithstanding the striking differences in the form of the calyx as well as of the corolla. The character of Brazoria was accordingly framed so as to embrace the two species, *B. truncata* and *B. scutellarioides.* But, through inadvertence, the synonym of *Hook. Bot. Mag.*, t. 3494, was cited under the former species, instead of being referred to B. scutellarioides, where it really belongs.

The genus is well distinguished, not only by the remarkable calyx, but by the manifestly didynamous stamens, the divaricating anther-cells, &c.

Brazoria truncata is a rather showy annual, with the stem nearly simple, or else branched from the base, about a foot high, terminated by a single spike, and sometimes with one or two lateral ones from its base. The corollas are an inch long, dull purplish rose-color,

* By a typographical error, the two numbers are transposed in the published account (*Plantæ Lindheimerianæ*); where the first, namely, *Brazoria truncata*, should be No. 287, and the second, *B.* (*Stachyastrum*) *scutellarioides*, should be No. 286. There is also an obvious transposition in the description of the calyx of B. truncata. The lobes of the "lower lip of the calyx," instead of the *upper*, are said to be "merely mucronulate in the middle," and "those of the upper," instead of the *lower*, as it should be, "erose-denticulate."

slightly striped and conspicuously dotted with deep purple; the lower lip is paler, and tinged with yellowish inside; the tube is pilose-annulate next the base. The stamens, inserted towards the summit of the tube, are a little exserted. In fruit, the spike, covered with the four-ranked persistent calyxes with their bracts, attains the length of six to nine inches. The calyx is then dry, scarious, and finely reticulated; the upper side is much more strongly gibbous than is shown in Fig. 9, so that the achenia are nearly concealed in the cavity; this is closed by the lower lip, which is now applied flatly against the upper, nearly covering its whole face. In *B. scutellarioides*, the lower lip is smaller and much narrower than the upper, but it covers the orifice in the same way.

The figure was made from specimens raised in the Cambridge Botanic Garden, from Texan seeds sent by Mr. Lindheimer.

Tab. V. *Brazoria truncata. Fig.* 1. Flowering stem, natural size. *Fig.* 2. Spike, with the summit of the stem, in fruit. *Fig.* 3. A flower, seen in front. (The lateral lobes of the lower lip are not represented as emarginate or two-cleft at the apex, which they almost always are.) *Fig.* 4. Upper lip of the corolla, with a portion of the tube. *Fig.* 5. Anterior part of the throat seen from within, to show the sort of palate. *Fig.* 6. Calyx and style, with the bract. *Fig.* 7. Fructiferous calyx, seen in front. *Fig.* 8. The same, seen laterally. *Fig.* 9. Front view of the same, with the lower lip separated and turned down. (The well defined and deep cavity at the base of the upper lip, inclosing the achenia, is not well shown in this figure, which was taken before maturity; nor is the fine reticulation of the calyx represented.) All the analyses are more or less enlarged.

SULLIVANTIA OHIONIS, *Torr. & Gray.*

TAB. VI.

SULLIVANTIA, *Torr. & Gr. adnot. in Sill. Journ.*, 42. *p.* 22.

Calyx inferne cum ovarii basi connatus, quinquefidus, æstivatione imbricativa quincunciali. Petala 5, parum irregulares, ovato-spathulata, acutiuscula, unguiculata, in sinubus calycis inserta, marcescentia; æstivatione imbricativa quincunciali. Stamina 5, ad basin calycis loborum inserta, iisdem opposita et breviora; antheræ cordato-ovatæ, apiculatæ, biloculares, longitudinaliter dehiscentibus. Ovarium stylis 2 brevissimis (stigmatibus simplicibus) bicorne, biloculare, placentis crassis dissepimento adnatis multiovulatis; ovulis adscendentibus. Capsula calyce fere inclusa eoque ad medium accreta, ovoidea, bilocularis, polysperma, apice per rostra brevia intus dehiscens. Semina sursum imbricata, scobiformia, testa laxa reticulata utrinque membranaceo-alata. Embryo fere albuminis carnosi longitudine: radicula cylindrica; cotyledonibus oblongis.

Herba perennis, dodrantalis; radice fibrosa; foliis plerisque radicalibus, glaberrimis, longe petiolatis, orbiculari-reniformibus sinu fere clauso, inciso-dentatis atque sublobatis, petiolis basi dilatatis; scapo gracili, reclinato, inferne alternatim uni – bifoliato, superne bracteato, paniculatim ramoso, una cum pedunculis laxe

cymoso-trichotomis calycibusque glanduloso-pubescentibus; floribus parvis (corolla alba calyce triplo superante); pedicellis brevibus, fructiferis decurvis.

S. Ohionis, ***Torr. & Gr., l. c.; Gray, Excurs. to Mount. N. Carol. in Sill. Journ. & in Hook. Lond. Journ. Bot.,*** **1.** ***p.*** **228;** ***& Bot. Textbook, ed.*** **1.** ***f.*** **38.**

Heuchera, n. sp.? *Sulliv. Cat. Pl. Columbus, Ohio.*
Saxifraga? Sullivantii, *Torr. & Gr. Fl. N. Amer.*, 1. *p.* 575.

Hab. In comitatu *Highland* Ohionis, ad declivia rupium calcariarum, in unico loco solum detexit cel. *Sullivant.* Floret Junio.

It is with peculiar propriety that this well marked Saxifragaceous genus bears its present name, since it has been found by no person except Mr. Sullivant, and is, so far as known, restricted to the State of Ohio. Indeed, it has yet been met with at a single locality only, in Highland county, on limestone cliffs which border a tributary of the Scioto, where, however, it grows in great abundance. The living plants, which Mr. Sullivant several years ago communicated to the Botanic Garden of the University, still continue to flourish on the steep slope of a simple rockwork, along with the allied *Boykinia aconitifolia* of Nuttall, the four species of *Heuchera* indigenous to the United States, *Saxifraga erosa*, *S. Careyana*, and an undescribed Saxifrage nearly related to the latter.*

* Saxifraga Caroliniana (sp. nov.): glanduloso-pubescens; foliis omnibus radicalibus deltoideis ovatisve grosse dentatis e basi pl. m. truncata in petiolum marginatum abrupte angustatis; scapo paucibracteato paniculato-cymoso effuso; petalis

The accompanying figure was taken from cultivated specimens, which perfectly accord with the spontaneous plant.

In the *Flora of North America*, this plant, then known through specimens in flower only, was doubtfully appended to a group of ambiguous pentandrous species of Saxifraga. Afterwards, when the fruit and seeds furnished additional characters, it was separated to constitute a distinct genus, dedicated to the zealous and excellent botanist who discovered it. At the same time, the transference of the remaining pentandrous Saxifrages (*S. Richardsonii* and *S. ranunculifolia* of Hooker) to Boykinia was proposed.*

Thus considered, the genus Sullivantia is clearly distinguished from all its allies, except the remarkable *Leptarrhena*, by its scobiform and somewhat winged seeds; also from *Heuchera* by its two-

consimilibus ovatis subunguiculatis albis infra medium pallide bimaculatis sepala reflexa duplo superantibus; filamentis clavatis; carpellis discretis demum divaricatis turgidis calyce liberis. — Variat foliis ovato-oblongis vel rotundato-reniformibus, basi aut subcordatis aut cuneatis. — HAB. In declivibus humidis opacis montium altiorum Carolinæ Septentrionalis. In horto floret Maio – Junio.

Living plants of this species were gathered by myself in the Alleghany Mountains of North Carolina, and probably of Virginia also, in the autumn of 1843, along with those of S. Careyana, which this species so nearly resembles that the difference was not detected until both came into flower the ensuing spring. The characters of the two remain constant under cultivation. S. Caroliniana is distinguished from S. Careyana by its reflexed (instead of barely spreading) calyx, its more strongly bimaculate petals (those of S. Careyana prove to be spotted also but very faintly), and its decidedly clavate filaments, which in S. Careyana are filiform. S. Caroliniana belongs, therefore, to the section *Hydatica.*

* *Bot. Excursion to the Mountains of N. Carolina, in Sill. Journ., l. c.*, p. 21. — Mr. Fielding, in his *Sertum Plantarum*, t. 57, has published a good figure of *Boykinia aconitifolia*, justly remarking that it has no characters sufficient to separate it from the pentandrous Saxifrages above mentioned. He therefore refers it to Saxifraga. I have preferred to refer *them* to Boykinia.

celled ovary; from *Saxifraga*, by its pentandrous flowers; and from *Boykinia*, by its less adherent calyx, persistent petals, and very short stamens, to which I may now add the imbricative æstivation of its corolla. For in B. aconitifolia the petals are convolute in æstivation; which character, if it shall be found to hold good in the two Oregon species (a point that the advanced state of my specimens does not allow me to verify), will abundantly confirm the genus Boykinia.*

TAB. VI. *Sullivantia Ohionis*, of the natural size. *Fig.* 1. A cymule, in fruit. *Fig.* 2. A flower. *Fig.* 3. Same, with the calyx laid open. *Fig.* 4. Cross-section of an unripe capsule. *Fig.* 5. Vertical section of the same. *Fig.* 6. A seed. *Fig.* 7. Longitudinal section of the same, displaying the embryo. All the analyses more or less magnified.

* This discovery strengthens the view I had formerly ventured to take, in appending *Philadelpheæ* to the order Saxifragaceæ (*Fl. N. Amer.* 1, p. 594), although other botanists think that there is only "some collateral relationship" between them. Excepting in the more numerous stamens, Philadelphus differs from Saxifragaceæ-Hydrangeæ only in the valvate calyx and convolute æstivation of the petals; the very characters which are unexpectedly exhibited in a true Saxifragea by Boykinia. Of course I follow De Candolle and Zuccarini in referring *Deutzia* — which has valvate petals and definite stamens — to the suborder Hydrangeæ; as also *Decumaria*, the petals of which, I believe, are not imbricated (as described by Endlicher), but valvate, with induplicate margins, like Deutzia, and which is very closely related to *Schizophragma*, Zucc., an undoubted Hydrangeaceous genus. (Vide *Fl. N. Amer.* 1, p. 593.) Lindley, however, in his *Vegetable Kingdom*, still comprises both Deutzia and Decumaria in his order Philadelphaceæ, although the ordinal character he assigns suffices to exclude them.

THERMOPSIS CAROLINIANA, *M. A. Curtis.*

TAB. VII.

" T. Caroliniana: caule virgato simplicissimo glabro subglauco; foliolis obovati-oblongis margine subtusque parce pubescentibus petiolo longioribus; stipulis (magnis) rotundatis amplexicaulibus, supremis petiolum subæquantibus; racemo spicato elongato stricto calycibusque pubescenti-villosis; floribus irregulariter confertis verticillato-subternisve; bracteis ovatis pedicellem duplo excedentibus calyce parum brevioribus; staminibus vix persistentibus; leguminibus villosissimis lato-linearibus rectis planiusculis rachi appressis.

T. Caroliniana, *M. A. Curtis, in Sill. Journ.* 44. (1843), *p.* 80; *Benth. in Lond. Journ. Bot.*, 2. *p.* 432.

Hab. In sylvis montanis comitatuum *Haywood* et *Cherokee* Carolinæ Septentrionalis hinc inde detexuerunt *Rev. M. A. Curtis* (anno 1839) et *S. B. Buckley* (1842). Floret Junio, Julio.

This is an upright plant, with remarkably strict, and, for the most part, entirely simple stems, three feet high, terminated by a single and rather compact raceme, or spike, of bright yellow blossoms. The foliage is light green, a little glaucous; the leaves all trifoliolate, with the leaflets varying from two and a half to four inches in length, smooth and glabrous, except a sparing pubescence

beneath. The stipules, which are perfectly persistent, are one to two inches long. The flowers are three fourths of an inch in length, on pedicels which are only one or two lines long, so that the inflorescence is rather to be called a spike than a raceme. The upper lobe of the campanulate calyx is merely emarginate. The vexillum, as in the remaining species, is clearly shorter than the other petals; the inside below the reflexion is dotted with brownish; the summit is rather deeply two-cleft, which is not shown in the figure. The stamens persist after the petals fall, but usually disappear before the fruit is grown. The fruit-bearing spike is eight or ten inches in length, frequently ripening twenty to forty crowded pods. The legumes are erect and closely appressed, densely silky-villous, quite straight, about two inches long and a fifth of an inch wide, obtuse at the base and almost sessile, 10 – 12-seeded, seldom at all constricted by the abortion of a part of the seeds; the valves are rather convex till the pod is quite ripe, when they are nearly flat. Seeds oval, slightly reniform.

When the first volume of the *Flora of North America* was published, the authors knew of no species of this genus indigenous to the proper United States. Three species are now known, from the State of North Carolina, and are in cultivation at the Cambridge Botanic Garden. Two of them were proposed and characterized by the Rev. M. A. Curtis, in *Silliman's Journal* for January, 1843; and the same assiduous and excellent botanist was also, probably, the first to detect, in the *Baptisia mollis* of Michaux, the third of our species of Thermopsis.

Mr. Curtis discovered the entirely new and striking Thermopsis Caroliniana in the summer of 1839, among the mountains of the southwestern corner of North Carolina, near Pigeon river, in Haywood county, and also on the Hiwassee river, in Cherokee county.

It has since been met with only by Mr. Buckley at other localities in the same region. I raised the plant in the Cambridge Botanic Garden (where it is perfectly hardy) from seeds taken from a fruiting specimen kindly communicated by Mr. Buckley. The species appears to be most nearly allied to the Californian T. macrophylla.

Mr. Brown distinguished the genus Thermopsis from Baptisia by its persistent stamens and linear compressed legumes.* The first-named character, however, is scarcely applicable to the present species, and not at all to the two succeeding, in which the stamens are quite as deciduous as in Baptisia. In fact, they differ from that genus by their slender and flat pods alone. Mr. Bentham † relies upon the persistent stamens, and some attenuation of the base of the calyx (a character inappreciable in American specimens), and admits two Himalayan species with oblong or ovate legumes, which in one are slightly, in the other greatly, inflated. The pods of *T. alpina* are likewise said to be elliptical-oblong, but compressed. It is very difficult, therefore, to make out the diagnosis of these two genera, unless, indeed, *T. inflata* of Cambessèdes be referred to Baptisia, and the distinction be made to rest entirely on the compressed legumes.

Tab. VII. *Thermopsis Caroliniana*, natural size. *Fig.* 1. Portion of the raceme in fruit (when fully ripe the legumes are flatter). *Fig.* 2. Immature legume, with cross-section.

* *Hort. Kew.*, ed. 2, Vol. III., p. 3.

† *London Journal of Botany*, Vol. II., p. 430.

THERMOPSIS FRAXINIFOLIA, *M. A. Curtis.*

TAB. VIII.

T. FRAXINIFOLIA : glaberrima, subglauca; caule ramoso ramisque flexuosis patentibus; foliolis ovato-oblongis basi cuneatis petiolum subexcedentibus ; stipulis lanceolatis petiolo brevioribus, summis præcipue rameabilibus minimis nunc deciduis; racemis laxifloris declinatis; pedicellis filiformibus sparsis patentibus calyce triplo longioribus bracteas subulatas multoties superantibus ; staminibus deciduis ; leguminibus elongato-linearibus vix falcatis planis cinereo-puberulis patentissimis.

Thermopsis fraxinifolia, *M. A. Curtis, in Sill. Journ.*, 44. *p.* 81.
Baptisia mollis, *Nutt. Gen.*, 1. *p.* 281, non *Michx.*
Baptisia fraxinifolia, *Nutt. MSS., ex Torr. & Gr. Fl. N. Amer.*, 1. *p.* 387.

HAB. In nemorosis ad " Table Mountain," Carolinæ Superioris, *Nuttall, Curtis,* etc.; atque in aliis locis inter montes comit. *Henderson* et *Macon* legit *S. B. Buckley.* Floret ineunte æstate.

This species has much the habit of Baptisia alba. The stems, which reach the height of about three feet, are more or less declined, and the numerous geniculate slender branches are widely spreading. These are nearly all terminated by a raceme, so that a succession of flowers is produced nearly through the summer; while *T. Caroliniana* and *T. mollis* bear only a single raceme. The stipules are quite variable ; the lowest being sometimes almost

as long as the petioles, though commonly much shorter; the upper ones are smaller, but occasionally ovate instead of lanceolate; those of the lateral branches are quite minute and inconspicuous, linear or subulate; and all, though they cannot be called deciduous, are apt to fall long before the leaves. The foliage is bright green, paler or glaucescent beneath; the leaflets about two inches in length. The declined racemes are very loosely flowered; the terminal ones are eight or ten inches long, and many-flowered; the lateral short and 10–20-flowered. The inconspicuous bracts resemble the uppermost stipules, and are somewhat deciduous. The spreading pedicels vary from half an inch to an inch in length. The flowers are one third smaller than in T. Caroliniana. The calyx is glabrous, the lobes or teeth much shorter than the tube, tomentose-canescent inside, the upper one strongly two-toothed. Corolla light yellow; vexillum slightly two-lobed. The stamens fall with the petals, or soon after, just as in Baptisia. The linear ovary is canescent. The minutely hoary legumes vary from two to three and a half inches in length, though scarcely two lines in breadth. They are quite flat, straight, or slightly curved, scarcely stipitate and quite even when all the (twelve to twenty) seeds ripen; but, from the abortion of a part, the pods are often constricted, and also narrowed at the base, as if much stipitate.

The figure is taken from the living plant brought by myself from Table Mountain. This is the very locality assigned by Nuttall to his Baptisia mollis, which he afterwards proposed to call B. fraxinifolia; but that part of his description which relates to the height of the plant, and its pubescence, is applicable only to the true Podalyria mollis of Michaux.

Tab. VIII. *Thermopsis fraxinifolia;* summit of a stem, with the terminal raceme in young fruit; of the natural size.

THERMOPSIS MOLLIS, *M. A. Curtis, MSS.*

TAB. IX.

T. MOLLIS: cinereo-pubescens; caule humili parce ramoso ramisque flexuosis subdeclinatis; foliolis oblongo-ovatis vel cuneato-ovatis petiolum triplo excedentibus supra glabratis; stipulis ovatis lanceolatisve, caulinis petiolo vix brevioribus vetustate deciduis; racemo solitario decurvato; pedicellis subalternis erectiusculis bracteas oblongas æquantibus flore brevioribus; staminibus deciduis; leguminibus elongato-linearibus subfalcatis planis canescenti-puberulis dependentibus.

Podalyria mollis, *Michx. Fl. Bor. Am.*, 1. *p.* 264.

Baptisia mollis, *DC. Prodr.*, 2. *p.* 100; *Torr. & Gr. Fl. N. Amer.*, 1. *pp.* 387, 695 (excl. syn. *Nutt.*); *M. A. Curtis, in Sill. Journ.*, 42. *p.* 81.

HAB. In rupestribus comitatuum Mecklenburg (*Michaux*), Lincoln (*Hunter*), Stokes (*Schweinitz*), Orange (*Curtis*), etc., Carolinæ Superioris, haud infrequens. Aprili – Maio floret.

This plant is about a foot high when it begins to flower; but as the stem still elongates, and the branches continue to develope, it attains twice that height, though it produces only a solitary raceme. The foliage is dull green, and the whole plant hoary with a minute appressed pubescence. The leaves, however, become nearly

glabrous with age. The stipules are variable; those of the branches smaller in proportion, often linear, and much shorter than the petioles they subtend; the cauline ones fall by the time the fruit is matured. The raceme, of bright yellow flowers, is four to six inches long, rather crowded, with the pedicels (which are scarcely longer than the calyx) alternate, or occasionally some of them rather verticillate-aggregated, or two to three from the same foliaceous bract. The flowers are three fourths of an inch long. The teeth of the campanulate calyx are nearly as long as the tube, triangular, and acute. The stamens are nearly as deciduous as in T. fraxinifolia; and the ovaries, as well as the legumes, are much as in that species.

This species, though still little known to American botanists, appears to be generally distributed throughout the middle and upper parts of North Carolina, doubtless extending northward and southward into the adjacent States; but, so far as known, it does not reach to the mountains. The most eastern locality is at Hillsborough, from which live plants were communicated to the Cambridge Botanic Garden by my esteemed friend, the Rev. M. A. Curtis. When Mr. Curtis cleared up the confusion that prevailed respecting this species and T. fraxinifolia, he still retained it in Baptisia, and described the legume, from imperfect and apparently abnormal specimens, as "oblong and turgid." But afterwards, on observing the perfect pods, he at once recognized it as a congener of his *T. fraxinifolia* and *T. Caroliniana.*

Tab. IX. *Thermopsis mollis;* whole plant. *Fig.* 1. Calyx and stamens. *Fig.* 2. Ovary, the calyx cut away. *Fig.* 3. A legume. All the figures of the size of nature.

GAYLUSSACIA URSINA, *Torr. & Gr.*

TAB. X.

G. URSINA : ramis divaricatis, junioribus ferrugineo-pilosis; foliis membranaceis deciduis ovato-oblongis acutis vel acuminatis mucronulatis viridibus puberulis subtus minute resinoso-atomiferis; racemo nutante 5–9-floro; pedicellis filiformibus bracteas caducas (inferiores foliaceas) excedentibus; corolla (viridi-rubella) globoso-campanulata; antheris vertice vix productis filamento ciliato brevioribus; fructu nigro.

Gaylussacia ursina, *Torr. & Gr. Fl. N. Amer.*, 2. *ined.*
Vaccinium ursinum, *M. A. Curtis, in Sill. Journ.*, 44. *p.* 82.

HAB. In sylvis montanis comit. Henderson, Haywood, Macon, etc., Carolinæ Superioris, invenerunt *Curtis, Buckley;* necnon ad summum scopulum mirabilem "Table Rock" dictum, Carolinæ Australis, ubi ipse legi. Floret Maio, Junio; fructus maturescit autumno.

Although so long overlooked by botanists, this species is very common through the mountains near the southwestern borders of North Carolina, where the fruit is known to the inhabitants by the name of *Bear-berry*, or *Bear Huckleberry*. It is doubless the plant which I find mentioned by the elder Michaux, in the manuscript diary of his travels through this region, under the name of "*Vac-*

cinium d'Ours"; but it is not described in his Flora.* The Rev. Mr. Curtis detected it, in the fruiting state, in the summer of 1839; and Mr. Buckley gathered the flowers in the spring of 1842. The next autumn I found it on the wooded summit of Table Rock in South Carolina, as well as elsewhere, and obtained living plants for cultivation in the Botanic Garden. Here it has blossomed, though sparingly, every spring, although it fails to ripen fruit. The shrub is only two or three feet high; the flowers are inconspicuous; and the fruit, though edible, and indeed not unpleasant when fully ripe (in September and October), has not the fine flavor of the other species, and is seldom eaten, except by the bears.

This plant, with the allied species, *G. resinosa, frondosa,* and *dumosa* (the true *Huckleberries,* as distinguished from the *Blueberries* of our markets), must be separated from Vaccinium, on account of their remarkable ten-celled ovaries, and drupaceous ten-seeded fruit. It is surprising that such an obvious peculiarity in some of our commonest summer fruits should have been so generally overlooked. Among the earlier writers, the only notices I can discover which point towards the true structure of the fruit are, that Wangenheim describes and figures his Andromeda baccata (which is Gaylussacia resinosa) as ten-seeded; † and Clayton describes another species as eight-celled, "with few osseous seeds." ‡ Muhlenberg, also, in his manuscript *Florula Lancastriensis,* expressly describes Vaccinium resinosum and V. frondosum as ten-seeded. Quite recently, when elaborating the *Vaccinieæ* for De Candolle's *Prodromus,* the learned Professor Dunal noticed some

* This manuscript journal was presented, by the younger Michaux, to the American Philosophical Society, Philadelphia, where it is preserved.

† *Anpflanzung Nordamericanischer Holzarten,* p. 111, t. 30, f. 69.

‡ *Flora Virginica,* ed. 2, p. 59.

fruiting specimens of one or more species with "baccis 8–10-locularibus! loculis monospermis?" But, instead of following this clew to the solution of this curious anomaly, he merely introduced a nominal species, *V. decamerocarpon*,* somewhat suspecting, indeed, that it might be a variety of V. frondosum, but unconscious that his four succeeding species shared in the peculiarity.

The next notice, expressly stating that this character is common to all the resinous-dotted species, and that the fruit is drupaceous instead of baccate, was published by myself in January, 1842, and the name of *Decachæna* was proposed for the group or genus.† In 1843, Mr. Nuttall established the same genus on the same species, under the somewhat similar name of *Decamerium*.‡ About the same time, on revising the Vaccinieæ for the *Flora of North America*, I was convinced that these plants are not generically distinguishable from *Gaylussacia*, and therefore referred them to that genus, from which they appear to differ in nothing but their deciduous foliage, — a character that will surely be deemed unimportant, while both deciduous and evergreen species are embraced in Vaccinium. In inflorescence, and in other respects, they quite accord with genuine species of Gaylussacia, and also in the resinous atoms with which they are more or less copiously sprinkled, but which are not found in any true Vaccinium. §

* "An genus distinctum? An Gaylussaciæ sp. foliis caducis? An var. decemlocularis V. frondosi?" *Dunal, in DC. Prodr.*, Vol. VII., p. 566.

† *Botanical Excursion to Mount. N. Car.*, in *Sill. Journ.*, Vol. XLII., p. 43; reprinted in Hooker's *Lond. Journ. Bot.*, Vol. III., p. 234 (in a note). The seeds were erroneously said to be *ascending*, instead of *suspended*.

‡ *Transactions of the American Philosophical Society*, Part 3d of Vol. VIII., New Series (1843), p. 259.

§ Although Mr. Nuttall (in *Trans. Amer. Phil. Soc.*, *l. c.*) remarks, that the habit of his *Decamerium*, as well as the geographical range, "is wholly different from

In the note already referred to,* I spoke of the fruit of these plants as if really decacarpellary (which is probably not the case); for, although I then stated that several of the more common true Vaccinia "exhibit a more or less completely 8–10-celled ovary, but with many ovules in each cell," yet I was not aware, until afterwards, of the mode in which the proper cells of the ovary are divided by a spurious partition, nor, indeed, has any account of it yet been published. The peculiarity in question, which was first shown to me in Vaccinium corymbosum by Mr. Sullivant, and afterwards by Dr. Torrey, in V. stamineum, — and which may be held to explain the increased number of cells in Gaylussacia, — is, that a projection of the back, or midrib, of each carpel extends into the cell until it meets (and sometimes coheres with) the corresponding placenta projecting from the axis, so as to divide each cell into two. This is represented in Tab. X., Fig. 6, as seen in Vaccinium corymbosum. A similar case has recently been brought to light, by Mr. Bentham, in *Nelitris* and some other baccate Myrtaceæ.†

This character may be turned to good account in reducing the Vaccinia to natural sections or subgenera.‡

Gaylussacia," yet, on the same page, one of his species is justly characterized as having "something of the habit of a Gaylussacia."

* *Bot. Excurs.*, &c., in *Sill. Journ.*, *l. c.*, Jan., 1842.

† *London Journal of Botany*, Vol. II., 1843, p. 221.

‡ The North American species may be disposed under the following sections: —

VACCINIUM, *Linn.*

§ 1. Oxycoccus. Ovarium 4-loculare, septis spuriis nullis. Corolla 4-partita, lobis elongatis revolutis. Antheræ exaristatæ: filamenta pilosa. — Flores solitarii axillares, vel in racemis fasciculisve terminalibus; pedunculis filiformibus.

* Foliis deciduis, caule erecto, baccis insipidis. — V. erythrocarpum, *Michx.*

** Foliis persistentibus, caulibus prostratis, baccis acidis. — V. Oxycoccus, *L.* V. macrocarpon, *Ait.*

It may be here mentioned that the flowers of *Gaylussacia resinosa* and *G. frondosa* are subject to a frequent monstrosity, in which the calyx and corolla become free from the ovary, somewhat fleshy, and enlarged to eight or ten times their natural size; the stamens being also thickened, misshapen, and imperfect. Of the same nature are the fleshy bodies borne by Azalea viscosa and

§ 2. VITIS-IDÆA. Ovarium 4–5-loculare, septis spuriis nullis. Corolla cylindrico- vel globoso-campanulata, 4–5-dentata seu 4-loba. Antheræ exaristatæ: filamenta pilosa. — Flores in racemis brevibus, bracteati et bibracteolati; foliis persistentibus. — (Vaccinii et Metagoniæ pars, *Nutt.*) V. Vitis-Idæa, *L.* V. myrtifolium, *Michx.* (V. crassifolium, *Andr.*) V. ovatum, *Pursh.*

§ 3. BATODENDRON. Ovarium pseudo-10-loculare. Baccæ (vix edulis) loculi abortu oligospermi. Corolla patenti-campanulata, 5-loba. Antheræ dorso 2-aristatæ: filamenta pilosa. — Flores in axillis foliorum ramealium solitarii, quasi racemosi, pedunculis filiformibus ebracteolatis.

* Foliis sempervirentibus, antheris inclusis, baccis nigris. — V. arboreum, *Marsh.* (V. diffusum, *Ait.*) (*Gen.* Batodendron, *Nutt.*)

** Foliis pallidis deciduis, antheris exsertis, baccis albidis. — V. stamineum, *L.* (V. elevatum, *Soland.*) (*Gen.* Picrococcus, *Nutt.*)

§ 4. EUVACCINIUM seu MYRTILLUS. Ovarium 5- rarius 4-loculare, septis spuriis nullis. Corolla subglobosa vel urceolata, 5–4-dentata. Antheræ dorso 2-aristatæ: filamenta glabra. — Boreali-alpinæ; foliis deciduis.

* Flores (sæpissime decandri) in axillis foliorum solitarii. — V. Myrtillus, *L.* V. Chamissonis, *Bong.* V. salicinum, *Cham.* V. myrtilloides, *Michx.* V. parvifolium, *Smith.* V. ovalifolium, *Smith.* V. cæspitosum, *Michx.*

** Flores (sæpius octandri) 2–4-nati e gemmis propriis. — V. uliginosum, *L.*

§ 5. CYANOCOCCUS (id est *Blueberry*). Ovarium pl. m. pseudo-10-loculare. Baccæ (dulces) pleiospermæ. Corolla cylindracea vel urceolata. Antheræ exaristatæ: filamenta pilosa. — Americanæ; fasciculis florum, vel racemis brevissimis, e gemmis squamosis propriis.

* Foliis sempervirentibus. — V. Myrsinites, *Lam.* (V. nitidum, *Andr.*)

** Foliis deciduis. — V. corymbosum, *L.*, cum spec. cognatis, vulgo *Blueberries.*

A. nudiflora, popularly known under the name of "*Swamp Apples.*" These are altered flower-buds, which, possibly on account of the puncture of insects (though of this I have seen no proof), develope in the form of solid succulent excrescences, half an inch to an inch in diameter, of irregular shape, but in which at first all the parts of the flower, though misshapen and obese, can often be distinguished. They obtain their full size at midsummer, when they have a not unpleasant acid flavor, and are greedily eaten by boys.

Since the foregoing account was prepared for the press, I have fortunately detected a true evergreen species of Gaylussacia, indigenous to the United States. The plant I refer to is the extremely rare *Vaccinium buxifolium* of Salisbury, the *V. brachycerum* of Michaux, which I have in vain sought for in the mountains of Virginia, but which has lately been discovered in Pennsylvania (in Perry county, near Bloomfield), by Professor Baird, of Dickenson College. From the specimens which this accomplished naturalist has obligingly sent me, I find that it has a ten-celled ovary, with a solitary ovule in each cell, instead of presenting the structure of the section *Vitis-Idæa*, with which the plant agrees in habit; and the fruit is evidently a ten-pyrenous drupe.*

* *Gaylussacia brachycera:* humilis, glaberrima; ramis angulatis; foliis (Buxi) ovalibus crenato-serrulatis; racemis subsessilibus glomeratis; pedicellis 2-bracteolatis brevissimis; corolla (rubro tincta) breviter campanulato-cylindracea; antheris in tubulos vix productis filamento ciliato brevioribus. — Vaccinium buxifolium, *Salisb. Parad. Lond.*, t. 4; *Bot. Mag.*, t. 928; *Bot. Cab.*, t. 648. V. brachycerum, *Michx. Fl.* 1, p. 234. !!

The habitat given in the Flora of Michaux is, "In Virginia, circa Winchester"; but the specimen in his proper herbarium at the *Jardin des Plantes* is marked "*Warm Springs.*" There are specimens in the herbarium of Muhlenberg, ticketed "Vaccinium Poxafolia, *Krien Preyer*," in the unmistakable chirography and orthography of Matthew Kin; from which I infer that this collector found the plant in

Tab. X. *Gaylussacia ursina ;* flowering branch of the natural size. *Fig.* 1. Lateral view of a magnified stamen. *Fig.* 2. The same, seen from within. *Fig.* 3. Fructified ovary magnified, with a cross-section showing the ten uniovulate cells. (The dots are resinous atoms.) *Fig.* 4. A detached pyrena of the fruit. *Fig.* 5. Section of the same, showing the seed. *Fig.* 6. Magnified transverse section of an ovary of *Vaccinium corymbosum.*

⁂ It may not be improper here to introduce a remark respecting certain dubious Ericaceous genera which appear to border on Aquifoliaceæ, namely, *Cyrilla*, *Cliftonia*, &c. Cyrilla was placed by Jussieu in his Ericeæ, and Cliftonia was referred to the same family by Sprengel. Lindley,* however, in 1836, referred them to the order Celastraceæ, with which they have little or no agreement, except in habit. In 1838, it was suggested, in the *Flora of North America*, that these genera, along with Elliottia, should constitute a suborder, Cyrilleæ, of the great family Ericaceæ, characterized by a polypetalous corolla, inappendiculate anthers opening longitudinally, and uniovulate cells of the ovary.† Endlicher, who had omitted Cyrilla and Cliftonia from the body of his *Genera Plantarum*, afterwards appended them to Ericaceæ in his first Supplement ; but subsequently, with much acuteness, joined the group Cyrilleæ to the order Ilicineæ, from which he considers them to differ only in the insertion of the petals and stamens (from the absence of a disk) upon the receptacle, and in having a larger embryo.‡ Recently, Dr. Lindley has raised the Cyrillaceæ to the rank of an independent order, which he places next to Olacaceæ in his most discordant alliance Berberales ; § distin-

Greenbrier county, Virginia. From this source, the fragment in the Willdenovian herbarium, communicated by Muhlenberg under the name of "Vaccinium coriaceum," was doubtless derived.

* *Introd. to Nat. Syst.*, ed. 2, p. 119.

† Torrey & Gray, *Flora N. Amer.*, Vol. I., p. 256 ; note under Celastraceæ.

‡ *Enchiridion Botanicum*, 1841, p. 578.

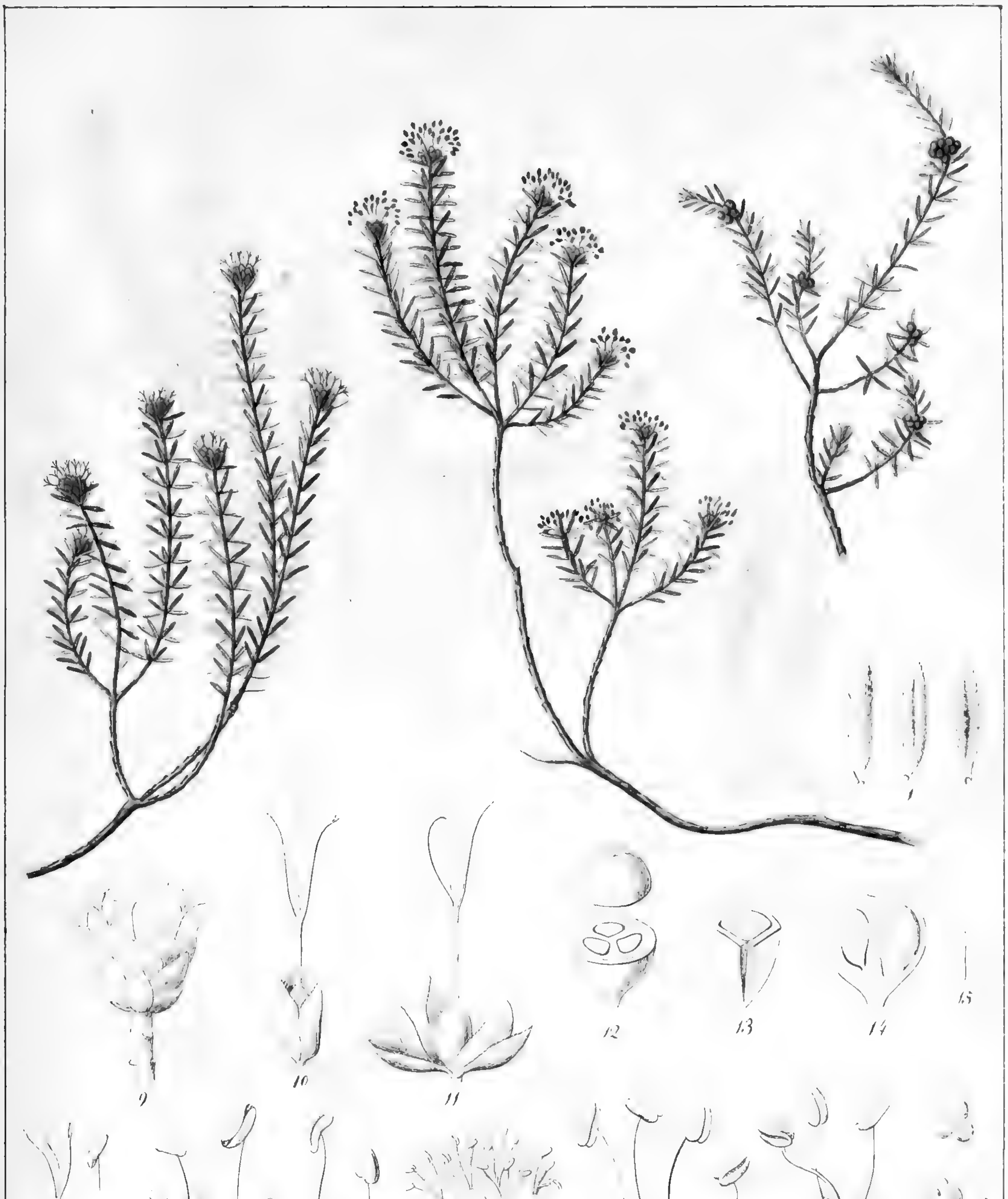
§ *Vegetable Kingdom*, 1846, pp. 432, 445.

guishing them, and indeed his whole alliance, from the Ericaceous group by a sole diagnostic character (the anisomerous cells of the ovary) which would not only exclude one of his genera, namely, Elliottia, but also embrace Clethra, Loiseleuria, Leiophyllum, &c. During the present year, M. Planchon has reëstablished the group as one of the primary divisions of Ericaceæ, with the diagnostic character of "Ericeæ petalis liberis, antheris inappendiculatis, fructu indehiscente (an semper ?), loculis monospermis," adding a new genus, *Purdiæa*, which, with the habit and much of the structure of Cliftonia, has a slender style, and anthers opening by terminal pores.*

The discovery of this interesting genus thus appears to prove that Cyrilla and Cliftonia were rightly referred to Ericaceæ ; although, on the other hand, Cliftonia is scarcely to be distinguished from the order Aquifoliaceæ except by the want of an hypogynous disk, the double number of stamens, the dry, instead of drupaceous, fruit, and the slender embryo. But Cyrilla further differs in another particular, which it is the principal object of this note to record. The seeds are indeed solitary, but the ovules are about three in each cell ; as is well shown in some analyses kindly made for me, in the spring of 1839, by M. Decaisne. I also find, on reëxamination with better specimens, that the ovary of Elliottia bears several (6–10) ovules in each cell, which are so small and so closely packed together on the short pendulous placenta, that they were mistaken for a single ovulum. The fruit is still a desideratum ; but, from the appearance of the ovary, I suspect it will prove to be capsular and septicidal ; so that, for the present, the genus should perhaps be placed next to Bejaria.

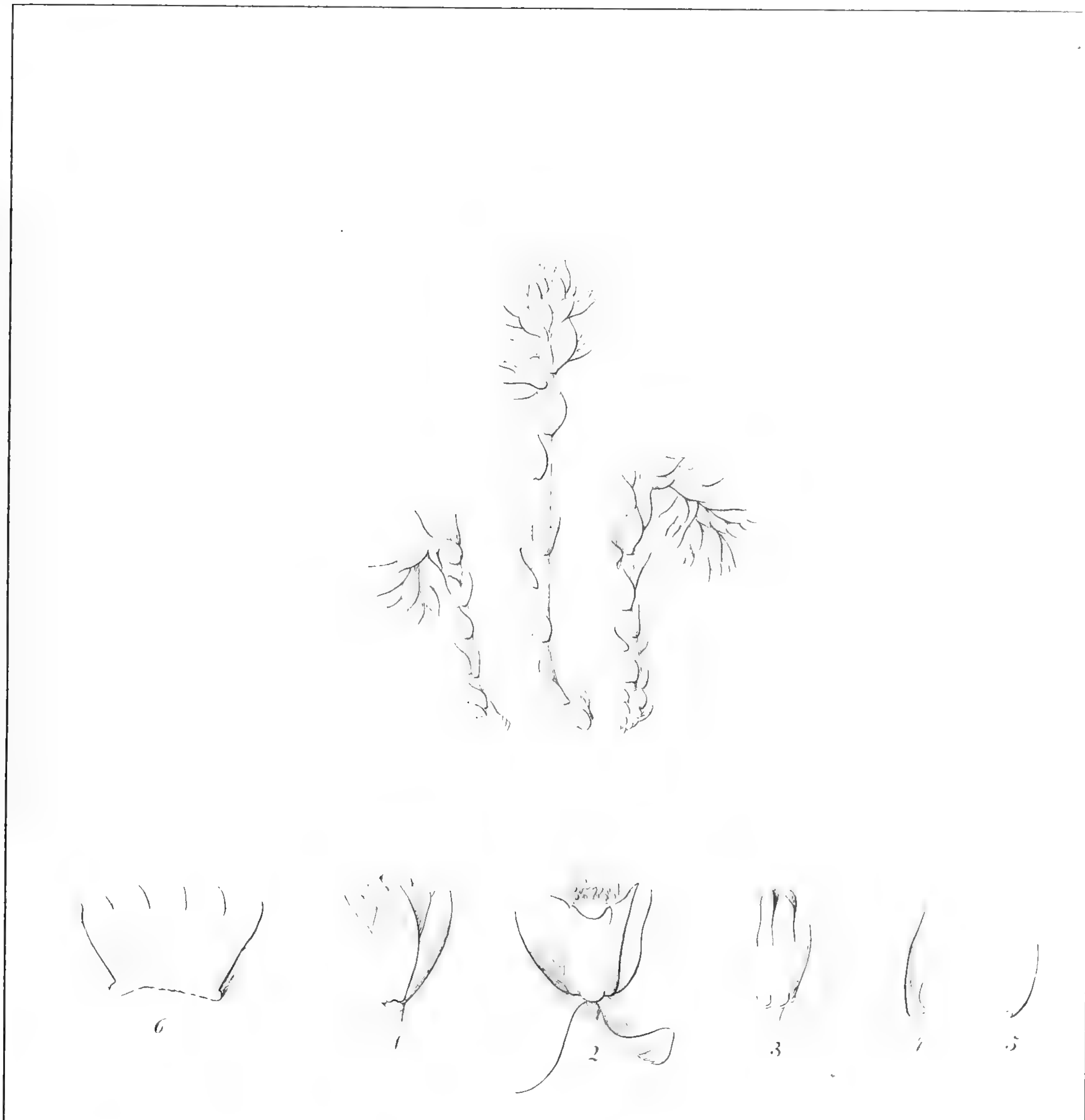
CORRECTION. The name of COREMA CONRADII has already been taken up by Dr. Torrey for the plant described in the first article of this memoir, in a letter to the late Mr. Loudon, cited in the *Gardener's Magazine*, Vol. XVII. ; and it is employed in Loudon's *Arboretum and Fruticetum Abridged*, p. 1092.

* *Description d'un Genre voisin du Cliftonia*, &c., in Hooker's *London Journal of Botany*, for May, 1846, p. 250, tab. 9.

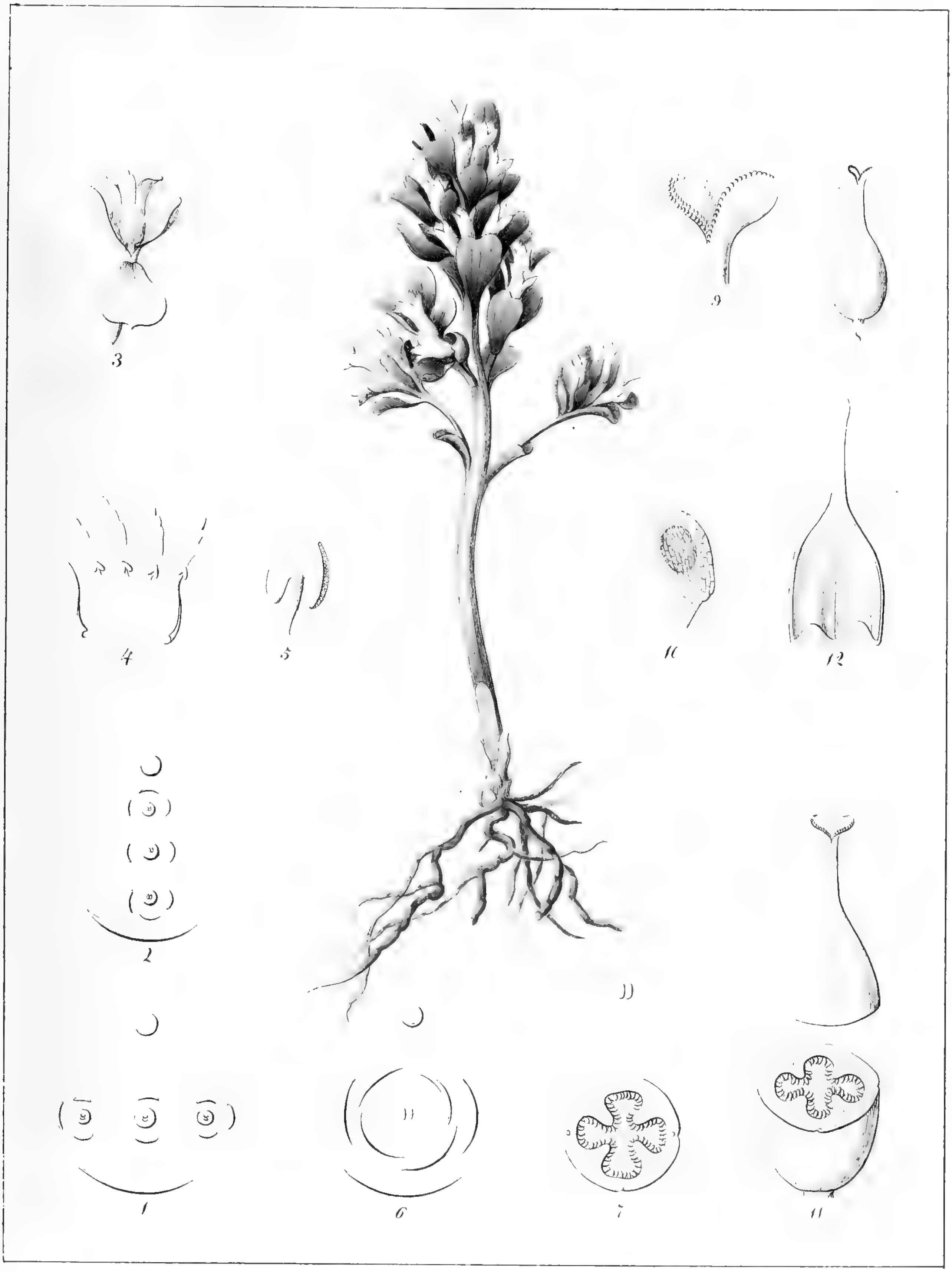


Sprague omnes del. Prestele omnes in lap. fc.

Oakesia Conradii.



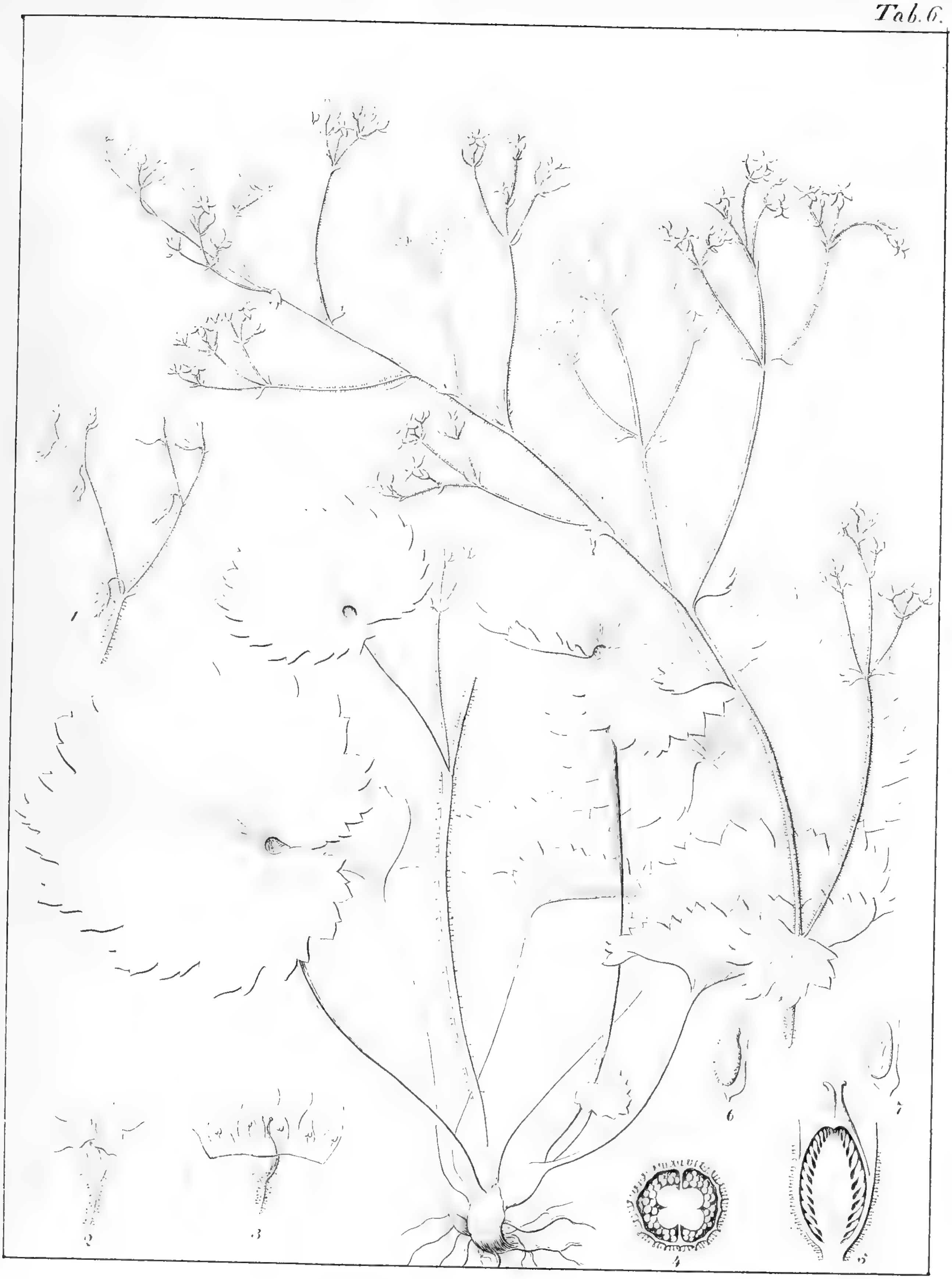
Schweinitzia odorata.



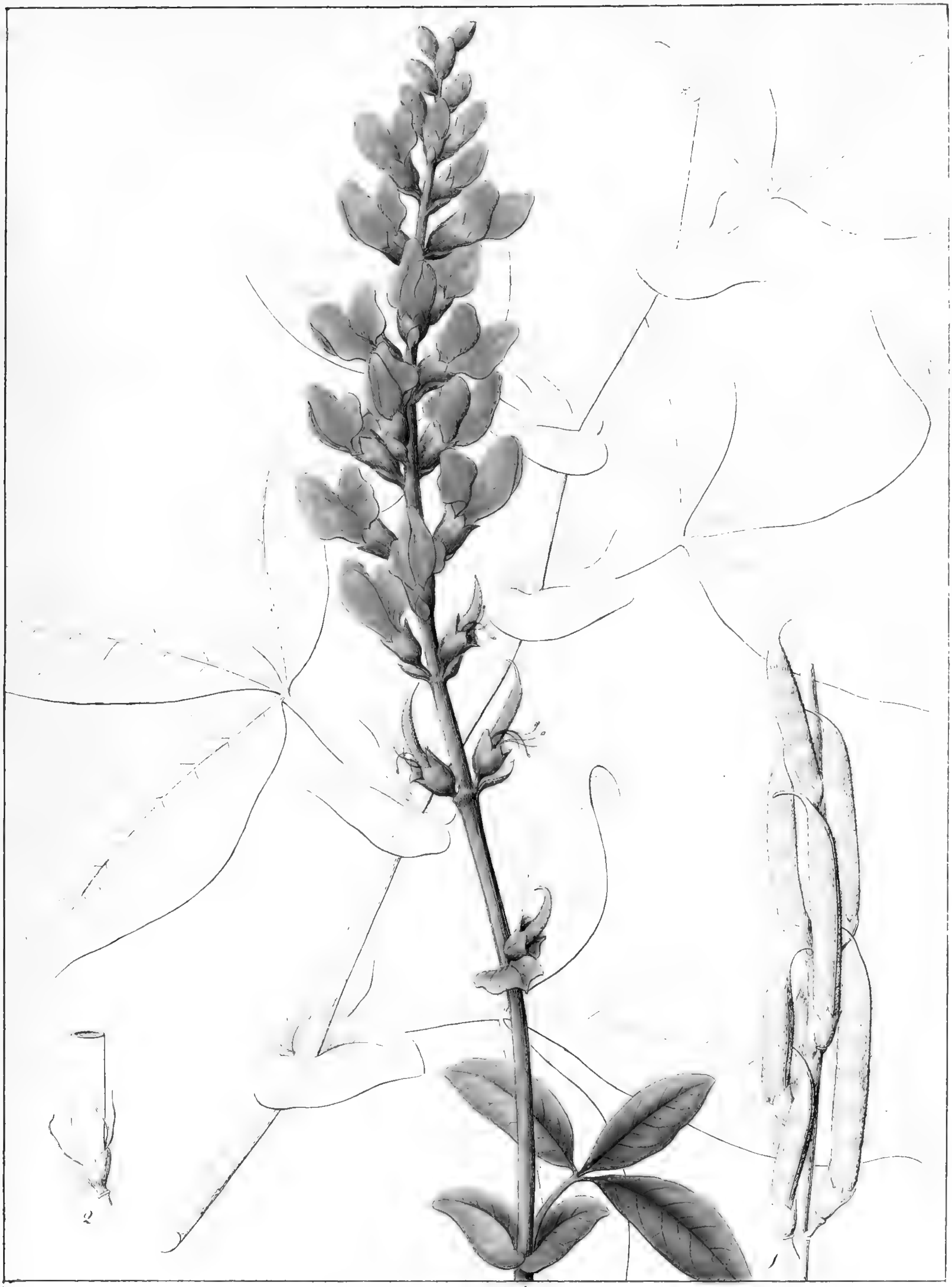
Obolaria Virginica.

Gaillardia amblyodon.

Brazoria truncata.



Sullivantia Ohionis.



Thermopsis caroliniana.

Thermopsis fraxinifolia.

Thermopsis mollis.

Gaylussacia ursina.

II.

Contributions to the Bryology and Hepaticology of North America.

By WILLIAM S. SULLIVANT.

PART I.

(*Communicated to the Academy, August 12th*, 1846.)

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1. PHYLLOGONIUM NORVEGICUM, *Brid. Bryol. Univ.* 2, *p.* 674. — *Musc. Alleghan. n.* 188.

It may be doubted if this rare moss and the tropical Pterigynandrum fulgens, *Hedw.*, the type of Phyllogonium, *Brid.*, are referable to the same genus. A striking dissimilarity in habit, mode of growth, and in the position of the female flowers (which are terminal in the one, but lateral in the other), as well as the structure and reticulation of the leaf, all indicate their separation generically. The genus of our moss must remain uncertain until the discovery of its fruit, which we may now expect, since a second locality has been found, in Ohio, producing both male and female plants abundantly. The notice of this moss in the *Bryologia Universa* is evidently founded on infertile plants alone, collected in Norway, the original locality. Our Ohio specimens furnish the following additional particulars.

Caules plerumque simplices, rarissime e medio vel e summitate innovantes. Folia, illis caulium sterilium exceptis, versus apicem

caulis sensim majora; floralia 4–6, erecto-patentia, longissime acuminata, acumine diaphano flexuoso subserrulato. Flores dioeci, in caule primario vel in innovationibus e summitate progredientibus terminales: uterque flos diphyllus; archegonia 8–12 stylo longissimo instructa, stigmate magno dilatato; antheridia 10–14, elongato-fusiformia, brevissime stipitata; paraphyses haud numerosæ, tenerrimæ, genitalibus utriusque sexus immixtæ, atque in foliorum superiorum gremio per paria nidulantes. Folia perichætialia et perigonialia floralibus similia, sed paulo majora.

It grows in large patches, pendent from the perpendicular faces of sandstone rocks, in moist, shady places, six or eight miles south of Lancaster, Ohio.

Tab. I. — *Fig.* 1. Plants of the natural size. *Fig.* 2. The same, magnified. *Figs.* 3, 4. Apices of cauline leaves. *Figs.* 5, 13, 14. Transverse sections of the leaf. *Fig.* 6. Cauline leaf. *Fig.* 7. Perichætial leaf. *Fig.* 8. Archegonia and paraphyses. *Fig.* 9. Perichætial leaves inclosing archegonia. *Fig.* 10. Antheridia and paraphyses. *Fig.* 11. Perigonial leaves inclosing antheridia. *Fig.* 12. Part of the stem. Magnified.

2. FISSIDENS MINUTULUS, *Sulliv. Musc. Alleghan. n.* 183.

Planta e perpusillis gentis, vitam annuam degens. Caules simplices, assurgentes, circiter sesquilineales, basi radiculosæ, dense gregariæ, sed nunquam inter se radiculis intertextæ. Folia erecto-patentia, 4–8-juga; inferiora minuta, remota, subsquamiformia; superiora in ascendendo magis magisque majora, oblique lineari-lanceolata, acuta, fere ad medium usque conduplicata; lamina apiciali subrepanda plus minus limbata; limbo haud incrassato e cellulis elongato-fusiformibus diaphanis conflato; costa pellucida, in apice evanescente percursa, rotundato-hexagone areolata. Flores dioeci,

terminales. Folia perigonialia 2, basi ventricoso-vaginantia, parte superiore conduplicaturæ eroso-truncata, cæterum caulinis similia; antheridia 3–4, filamento brevissimo suffulta, paraphysibus nullis: perichætialia 2, caulinis superioribus conformia sed longiora. Capsula erecta, symmetrica, ovalis, inferne attenuata, siccitate sub ore dilatato constricta: pedicellus 1 lineam longus, e basi geniculata flexuoso-ascendens, siccus sinistrorsum tortus: peristomii dentes erecto-incurvati, rubelli, apice ultra medium fissi, dense articulati, cruribus inæqualibus subulatis granuloso-scabris: operculum conico-rostratum; rostro recto, aut vix curvato, dimidiam capsulæ partem longitudine æquante: calyptra solum operculum obtegens, conico-subulata, uno latere profunde fissa: sporæ majusculæ diametro æquantes dentis basi dimidiam latitudinem.

This species grows on stones in the bed of desiccated rivulets, in shaded places, near Columbus, Ohio; it fruits in July and August.

Besides other marks of less importance, the diœcity of this moss readily distinguishes it from F. incurvus, *Br. & Sch.*, small forms of which it much resembles. The character in the foregoing description, drawn from the relative length of the diameter of a spore and the breadth of a tooth of the peristome near the base, may be made available in many cases for distinguishing species. In the present species and its nearest ally, F. incurvus, this character is efficient, since in the latter a spore equals one third the breadth of the peristomal tooth. In the F. obtusifolius, *Wils.*, the spores are unusually large, one being more than sufficient to cover the breadth of a tooth.

Tab. II. *A.*—*Fig.* 1. Plants of the natural size. *Figs.* 2, 4. Capsules. *Fig.* 3. Calyptra. *Fig.* 5. Female plant. *Fig.* 6. Male plant. *Fig.* 7. Antheridia. *Fig.* 8. A leaf. *Figs.* 9, 10. Portions of a leaf. *Fig.* 11. Portion of the peristome. *Fig.* 12. Spores. All except Fig. 1 more or less magnified.

3. FISSIDENS EXIGUUS, *Sulliv. Musc. Alleghan. n.* 182.

F. annuus, dioicus; caule simplici; foliis 5–9-jugis oblongo-lanceolatis immarginatis integerrimis, costa sub apice dissoluta; capsula terminali subobliqua vel erecta; operculo conico-rostellato; calyptra cuculliformi; flore masculo terminali.

Species præcedente dimidio major, folia minus elongata immarginata, capsula sæpius inæqualis subobliqua, sporæ minores.

It grows with the preceding species, and fruits at the same time.

Tab. II. *B.* — *Fig.* 1. Plants of the natural size. *Fig.* 2. Point of the leaf. *Figs.* 3, 6. Capsules. *Fig.* 4. Calyptra. *Fig.* 5. Female plant. *Fig.* 7. A leaf. *Fig.* 8. Antheridia. *Fig.* 9. Male plant. *Fig.* 10. Sections of leaves. *Fig.* 11. Spores. All magnified.

4. SCHISTIDIUM SERRATUM, *Hook. & Wils. in Drum. Musc. Amer. n.* 20. — *Musc. Alleghan. n.* 198.

This plant may be regarded as a highly developed state of the European Phascum patens; from which it is distinguished mainly by the firmer texture of the outer thecal membrane, and by a reduced form of opercular dehiscence. Its globose capsule separates at maturity into two equal portions by a circumscissile line, of which no traces are visible during the early stages of the plant, and no alteration, other than a slight discoloring of the cells near the line of separation, takes place; thus exhibiting an imperfect form of dehiscence in a moss of the operculate division.

The accordance of this plant with Phascum patens appears to be complete in all other important respects.

It may be here noticed, that the position and structure of the male flower of P. patens has been incorrectly described and figured by authors as terminal, and borne upon proper branches arising from the base of the main stem. Such is by no means the case. The male flower, as in Schistidium serratum, is situated near the female, rarely mixed with it, in the axils of the floral or upper leaves, either of the main stem or its innovations; the antheridia, 3–5 in number, are accompanied by paraphyses with globose terminal cells; and rudimentary perigonial leaves are occasionally present. All the North American specimens of P. patens, so called, that have come under my observation, belong to immature states of Schistidium serratum; but future examination may show that the two plants are less distinct than is at present supposed.

Our plant, as now understood, cannot be referred to the genus Schistidium of Bridel, much less to that of Bruch & Schimper; nor does it agree with any other well defined genus. With Physcomitrium, *Br. & Sch.*, it has many characters in common, and, in fact, the position of the male flower presents the only essential point of disagreement.

The plant is annual, and is often met with in the Middle and Western States, on rich soil, particularly near the margins of streams subject to inundation; it fruits during the summer and autumnal months.

Tab. II. *C.*—*Fig.* 1. Plants of the natural size. *Fig.* 2. Part of a plant, showing the capsule, operculum, and the position of the male flowers. *Fig.* 3. Spores. *Fig.* 4. Calyptra. *Fig.* 5. Antheridia with paraphyses. *Fig.* 6. Plant with a simple stem. *Fig.* 7. A portion of leaf. *Fig.* 8. A plant with innovations. All magnified.

5. MARCHANTIA DISJUNCTA, *Sulliv. Musc. Alleghan. n.* 286.

M. dioica; receptaculo fœmineo excentrico subseptem-radiato, radiis apice cuneato-dilatatis emarginato-crenulatis subtus dense barbatis; involucro 1–3-carpo subintegerrimo; receptaculo masculo semicirculari 7-radiato, radiis usque ad brevem pedunculum discretis; fronde dichotoma et articulatim innovante: cætera *M. polymorphæ.*

This, the second species of the genus known to the flora of the United States, differs strikingly from all others in its male receptacle. It has nowhere been found except on the high banks of the Alabama river, near the town of Claiborne, where I met with it in May, 1845.

Tab. III. — *Fig.* 1. Female plant, natural size. *Fig.* 2. Male plant, natural size. *Fig.* 3. Male receptacle, with a portion of the frond. *Fig.* 4. Transverse section of a ray of the male receptacle. *Fig.* 5. A gemmiferous cup. *Fig.* 6. Portion from the margin of the same. *Fig.* 7. Gemmæ. *Fig.* 8. Female receptacles. *Fig.* 9. Perpendicular sections of the same. *Fig.* 10. Perianth and calyptra. *Fig.* 11. A young pistil. *Fig.* 12. Chaffy scales of the receptacle. *Fig.* 13. Transverse section of the peduncle. *Fig.* 14. Spores and an elater. *Fig.* 15. Portion of a radicle. All the analyses are more or less magnified.

6. ANEURA SESSILIS, *Musc. Alleghan. n.* 280.

Jungermannia sessilis, *Spreng.* — *Lehm. Pugill.* 4, *p.* 34. — *Hook. & Wils. in Drumm. Musc. Amer. n.* 174.

The notices heretofore taken of this species appear to have been drawn from imperfect specimens of the female plant. Aneura ses-

silis is diœcious, with the antheridia embedded in the upper and concave surface of elongated tapering and deflexed processes, which, in clusters of 2–4 together, proceed from the margin of the frond. The capsule, in its normal state, is borne upon a long exserted pedicel; and even in cases where the capsule is apparently sessile (whence the specific name), the pedicel is of the usual length, but is folded up within the calyptra, whose thick substance resists its protrusion.

This species belongs to the Southern States; it fruits copiously in the cypress swamps around New Orleans, always growing on decayed logs. It is occasionally found as far north as in central Ohio, where, however, it requires artificial protection to mature its fruit.

TAB. V.—*Fig.* 1. Female plant, natural size. *Fig.* 2. Male plant, natural size. *Fig.* 3. Portion of a frond, with marginal processes or male receptacles. *Figs.* 4, 5, 6. Male receptacles. *Fig.* 7. Portion of a frond, with calyptra, pedicel, and capsule. *Fig.* 8. Young fruit. *Fig.* 9. Transverse section of a calyptra. *Fig.* 10. Upper part of a calyptra. *Fig.* 11. Valves of the capsule in a dry state. *Fig.* 12. The same in a moist state. *Fig.* 13. Upper part of a valve of the capsule. *Fig.* 14. Elaters and spores. *Fig.* 15. Portion of a valve of the capsule. *Fig.* 16. Transverse section of the same. *Fig.* 17. Transverse section of the frond. The analyses are more or less highly magnified.

7. AMONG the most remarkable of North American Hepaticæ is one found near Salem, in North Carolina, by the late Mr. Schweinitz, which he made known in his *Specim. Fl. Amer. Sept. Crypt.* (1821), under the name of *Targionia orbicularis.* Subsequently, he proposed to establish for it his new genus *Carpobolus*, of which he gave a detailed description and figure in the *Journ. Acad. Nat. Sci. Philad.* (1822).

Since the discovery, in Ohio, of two other plants, congeners with that of Mr. Schweinitz, it became necessary to reform the generic characters. The generic name has also been changed to *Notothylas;* the name of Carpobolus having been previously applied to a genus of Fungi, which is still retained by some authors; furthermore, its etymology conveys an idea inapplicable to these plants.

The genus and its species are thus characterized in the *Musci Alleghanienses:* —

NOTOTHYLAS, *Sulliv. Musc. Alleghan. n.* 289, 290.

Carpobulus, *Schweinitz, in Journ. Acad. Nat. Sci. Philad.* 2, *p.* 336. (1822).
Targioniæ spec., *Schweinitz, Specim. Fl. Amer. Sept. Crypt. p.* 23. (1821). — *N. ab E., Europ. Leberm.* 4, *p.* 317.

Monoica. Fructus dorsales, sparsi. Involucrum sessile, frondi continuum, initio clausum, tandem superne fatiscens. Perianthium nullum. Calyptra . . . . . Capsula involucro inclusa, oblongo-sphæroidea, compressa vel ovato-cylindrica, brevissime pedicellata, pedicello in bulbo incrassato affixo, sutura longitudinali ab apice ad medium subbivalvatim, vel sutura deficiente frustulatim, dehiscens. Columella linearis. Sporæ quaternatim aggregatæ, subglobosæ, læviusculæ. Antheridia frondi immersa, elliptico-globosa. Frons orbicularis, laciniata, tenera, papuloso-reticulata, margine undulato-crispa, subtus radiculosa, massis granulatis hic illic immersis.

Plantæ annuæ, terrestres, limicolæ, in umbrosis Ohionis, Carolinæque Septentrionalis observatæ.

1. N. ORBICULARIS, *Sulliv.* (Carpobolus orbicularis, *Schweinitz, l. c.*) involucro suberecto; capsula oblongo-ellipsoidea compressa cum vel absque sutura concolori: cætera ut in *N. valvata.*

Diagnosis secundum specimina *Schweinitziana* in Herb. *Acad. Nat. Sci. Philad.*

HAB. In Carolina Superiore prope Salem.

2. N. VALVATA, *Sulliv.*: fronde diametro tri-octolineari; involucro horizontali deflexo corniformi; capsula elongato-cylindrica curvula sutura colorata semper instructa; sporis luteolis subfuscisve.

HAB. In humidiusculis circa Columbus Ohionis, sat frequens.— Maturescit Æstate-Autumno.

3. N. MELANOSPORA, *Sulliv.*: capsula sutura omnino nulla; columella appendiculata; sporis atrofuscis dimidio majoribus quam in præcedente: cætera conveniunt.

HAB. In iisdem locis cum priore; rarissima.

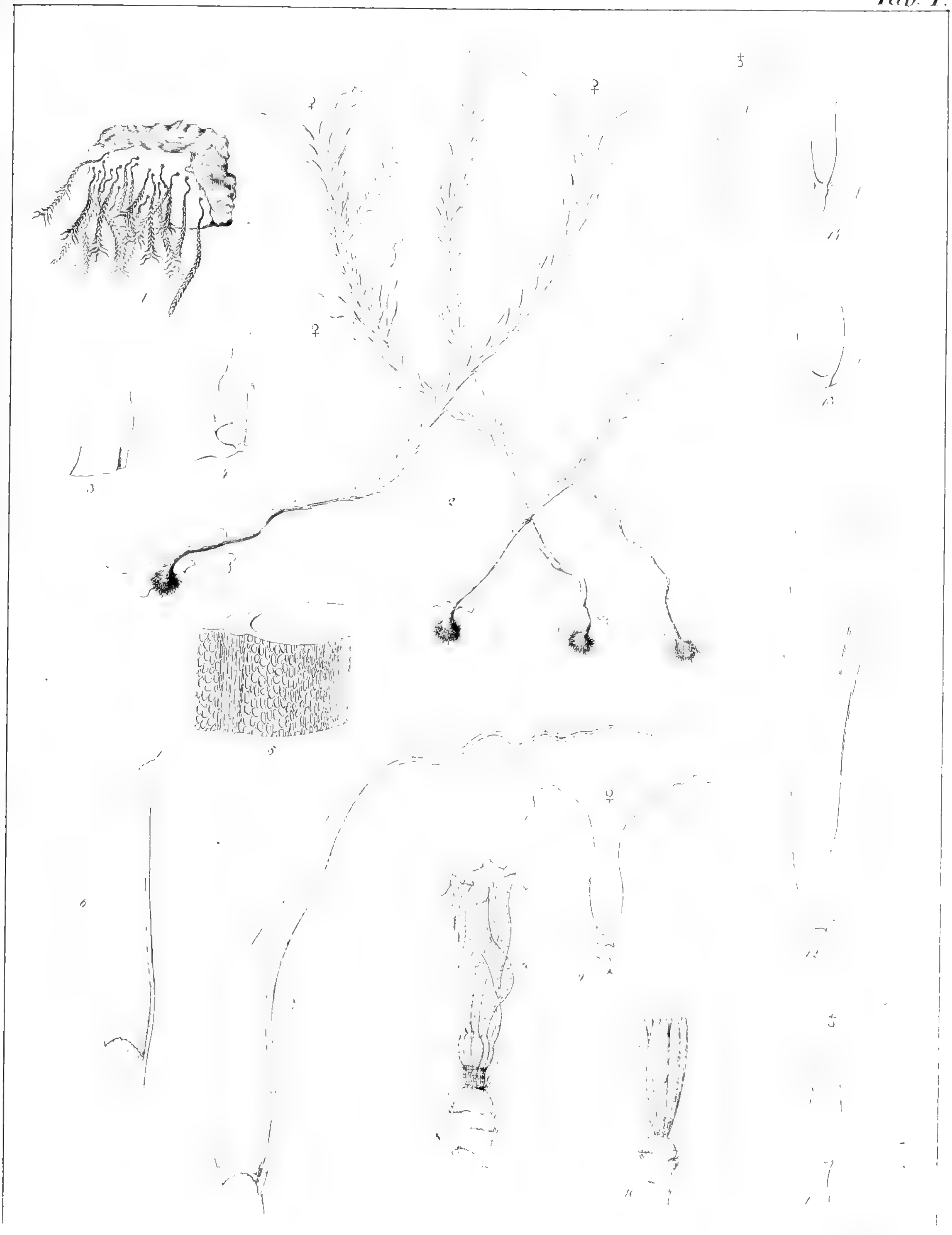
We have here a genus that cannot be placed in any of the tribes of Hepaticæ as now circumscribed. Its station is between Anthoceroteæ and Riccieæ. The frond is undistinguishable from that of Anthoceros, to which genus it also approaches in its tendency to bivalve dehiscence, in the presence of a columella, and in the manner of ripening the spores, which commences at the apex of the capsule and proceeds towards its base, so as to present spores in all stages of development. A relationship to Riccia is shown by the inclosure of the subsessile capsule in the frond, or rather in a protruded portion of it, as also by its embedded anthers, and the absence of any thing like elaters. Unlike both of the above genera, the calyptra, if present at all, vanishes at an extremely early stage of the plant's growth; for, in many dissections of N. valvata and N. melanospora, at all periods of growth, I have never seen a calyptra. The only

indication of its existence is the bulb at the base of the capsule, which may be the rudiment of that organ. Mr. Schweinitz appears to have detected no calyptra, and my examination of authentic specimens of the same species gave a similar result. I was, however, able to verify the presence of the columella pointed out by him in his first notice of the Southern species, but which, in his second and more extended account, is not referred to. With regard to the three species here given, it can hardly be questioned that N. orbicularis is distinct from the Ohio species; but that the two plants are equally distinct from each other is not so entirely free from doubt. Still, the specific characters assigned them have thus far proved constant. What phases other localities may produce remain to be seen; for the present (with Nees), "malo peccare in discriminandis quam in confundendis rerum naturæ cognitionibus."

Tab. IV. *A. N. valvata.* — *Fig.* 1. Plants of the natural size. *Fig.* 2. Portion of the frond, with an involucre and capsule. *Figs.* 3, 4. Involucres and capsules. *Fig.* 5. A capsule dissected, showing the columella. *Fig.* 6. Vertical section of an involucre and a portion of the frond, exposing the capsule. *Fig.* 7. A capsule dehiscing by its suture. *Fig.* 8. Spores. *Fig.* 9. Upper part of a capsule, showing the line of dehiscence and reticulation. *Fig.* 10. Portion of a frond, showing the imbedded anthers and masses of granules. *Fig.* 11. Antheridia. *Fig.* 12. Mass of granules. All magnified.

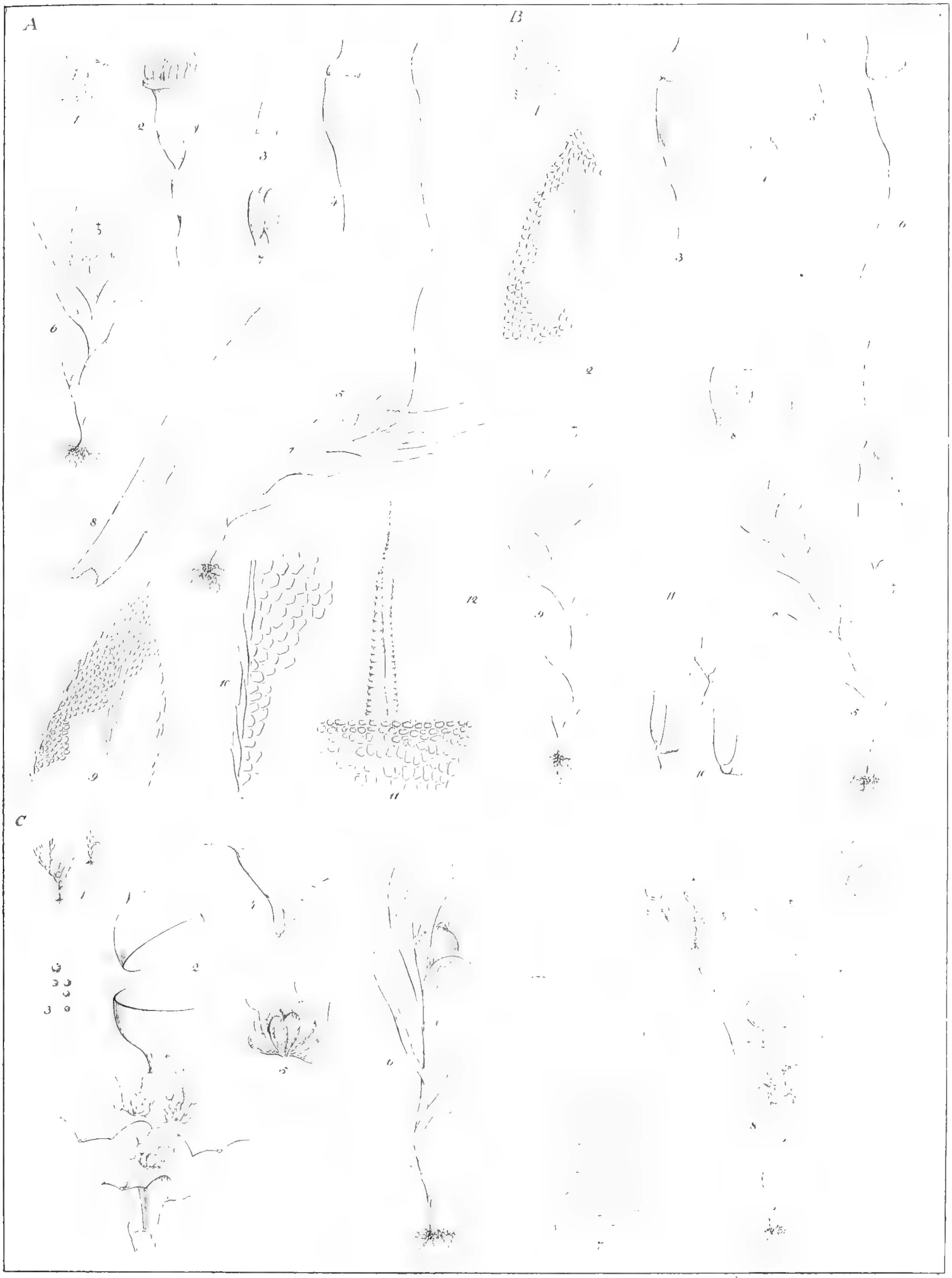
B. N. orbicularis. — *Fig.* 1. Plant of the natural size. *Figs.* 2, 3. A portion of the frond, with fruit. *Fig.* 4. Involucre and capsule. *Fig.* 5. Capsule bursting irregularly. *Fig.* 6. Spores. The analyses all magnified.

Columbus, Ohio, *June*, 1846.



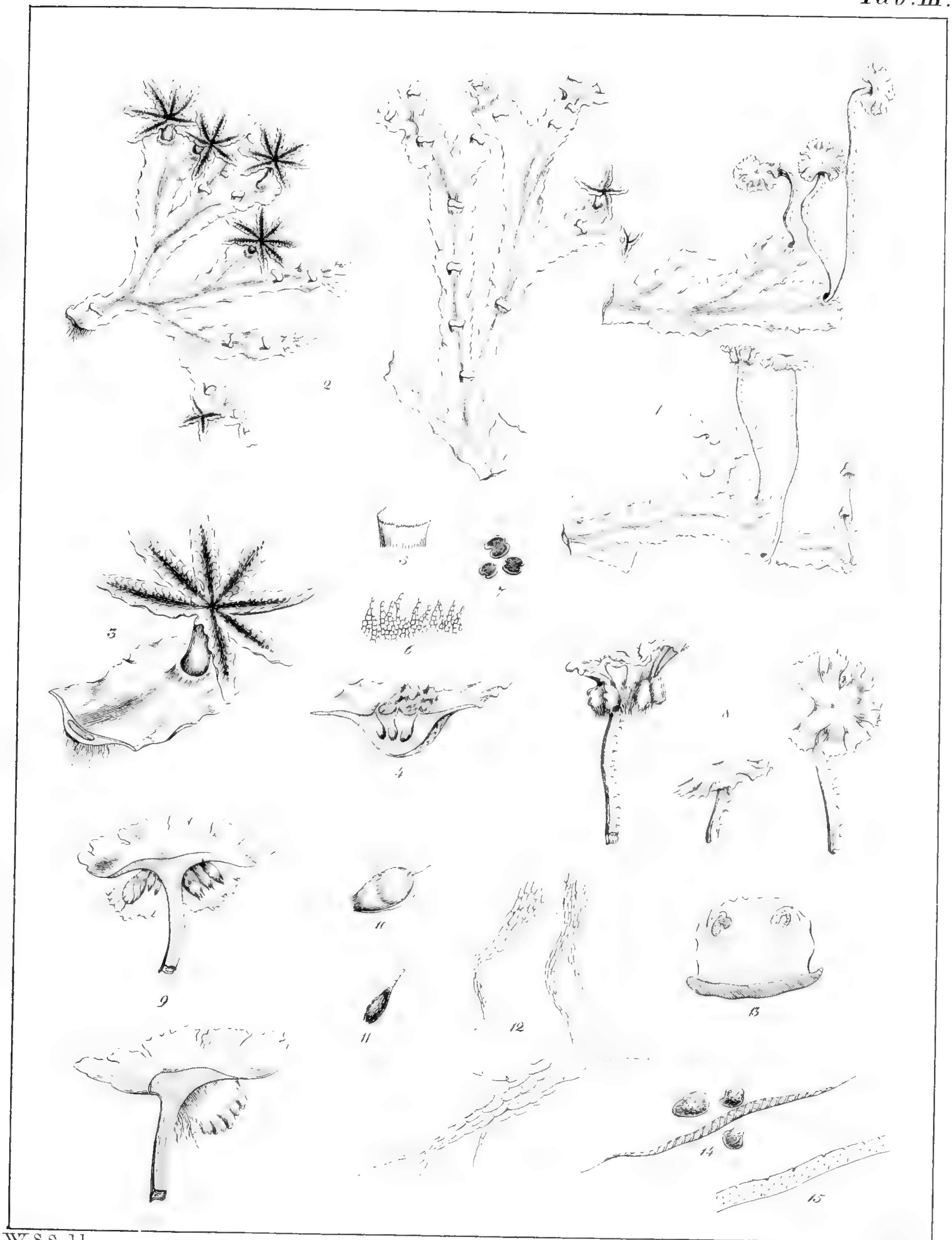
W. S. S. del.

Phyllogonium Norvegicum.



W. S. S. del.

A. *Fissidens minutulus*, B *F. exiguus*.
C *Schistidium serratum*.

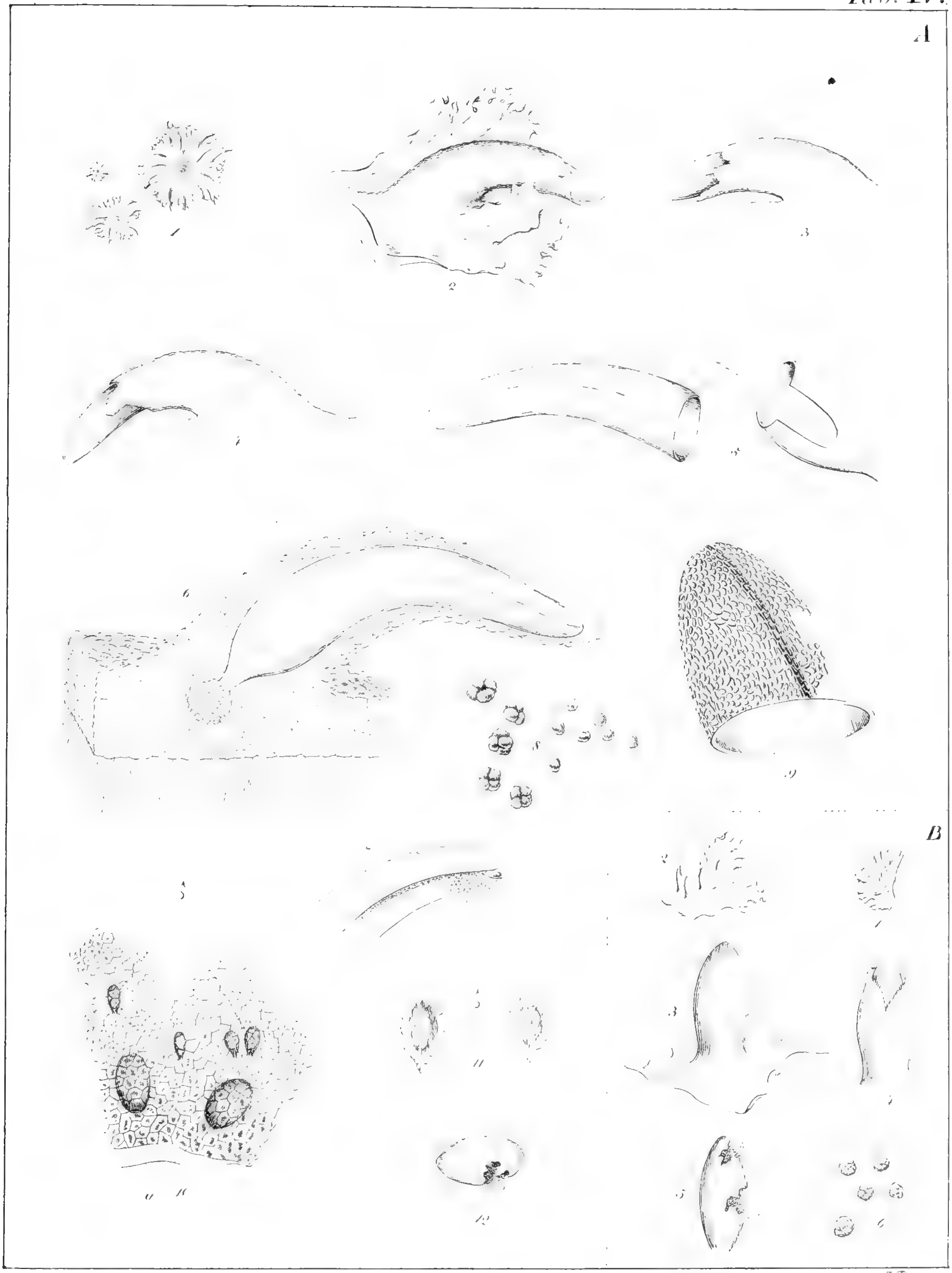


W. S. S. del.

J. P. sc

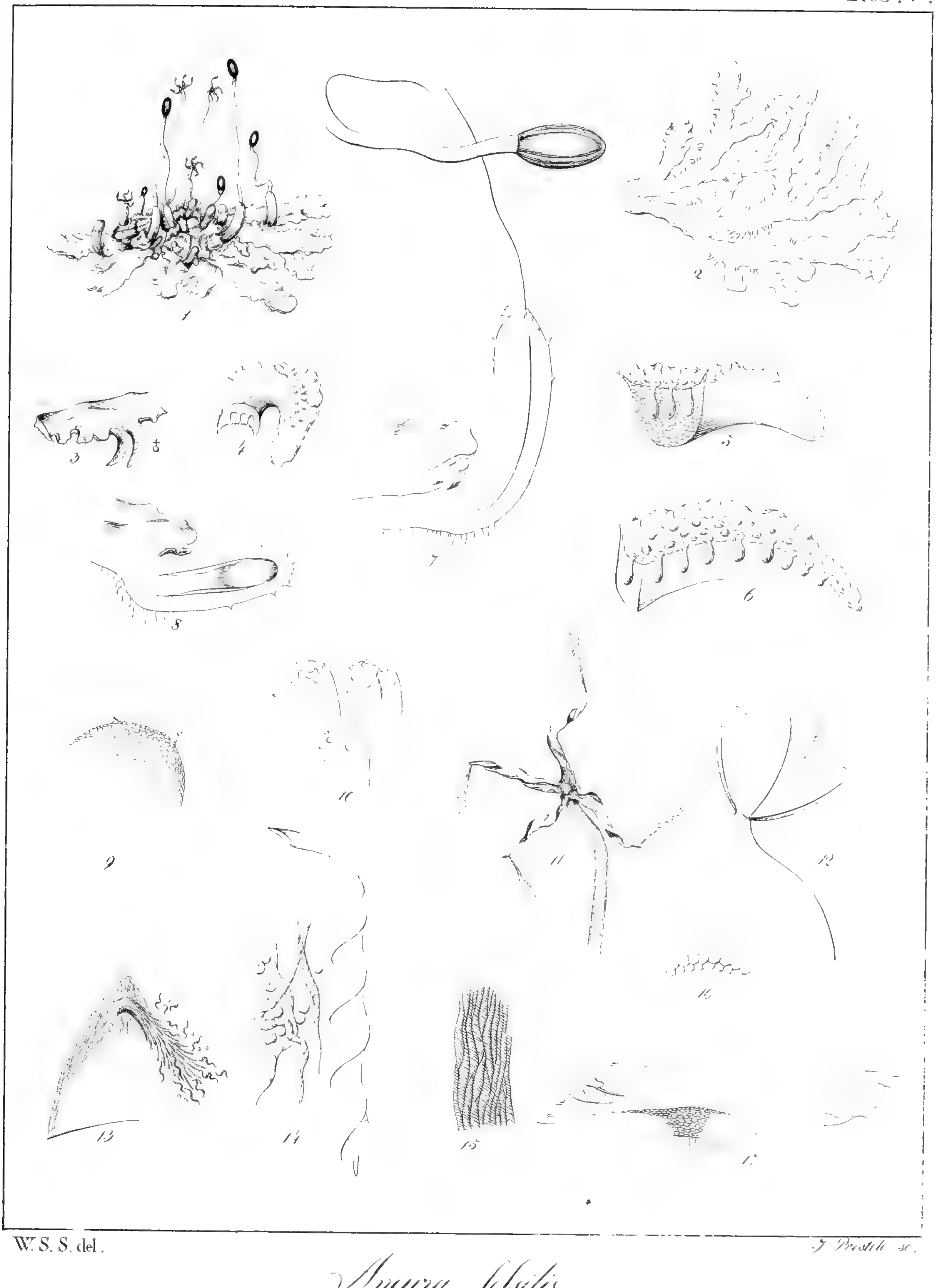
Marchantia disjuncta.

Tab. IV.



W. S. S. del. · J. P. sc.

A · *Notothylas valvata*, B *orbicularis*.



W. S. S. del.

J. Prestel sc.

Aneura sessilis.

III.

Occultations and Eclipses observed at Dorchester and Cambridge, Massachusetts.

BY WM. CRANCH BOND, A. M.,
DIRECTOR OF THE OBSERVATORY,

WILLIAM. C. BOND, JR.,

AND

GEORGE P. BOND.

(*Communicated to the Academy, August 12th,* 1846.)

THE series of observed eclipses of the sun and moon, and occultations of stars and planets, which are herewith presented to the Academy, were observed from three different stations. The first portion of them from my late residence at Dorchester; the second, from a position near Harvard Hall, in Cambridge; and the third, from the new Observatory.

The relative bearings and distances of these points have been accurately determined, and each one of them has been connected with three points of the main triangulation of the State, by Simeon Borden, Esq., superintendent of the State survey, and his assistant, Charles O. Boutelle, Esq.

The latitude and longitude of each has been separately ascertained from astronomical observations, and the resulting positions are given at the head of their respective divisions.

The whole series is now in process of final reduction, and, from

the close proximity of the stations, may be concentrated on the new Observatory without danger of sensible error arising from an erroneous estimate of relative position. This important work would be greatly facilitated by the communication of corresponding European observations.

In the column headed "Observer," B. denotes that the observation was made by Wm. Cranch Bond; W., by W. C. Bond, Jr.; B.², by G. P. Bond.

The instrument generally employed for the earlier observations was a reflector of four inches aperture. For the last six years, two achromatics of three and two and three fourths inches aperture, and of nearly four feet focal length, equatorially mounted, have been used.

The occultation of Jupiter, March 29th, 1846, was observed with an equatorial, of four and one fourth inches aperture, and five feet focal length.

OCCULTATIONS AND ECLIPSES,

Observed at Dorchester. Lat. 42° 19′ 17″. Lon. 4ʰ 44ᵐ 17ˢ W.

Date.	Name of Star.	Mean Solar Time of Occultation. h. m. s.		Observer.	Remarks.
1820, Nov. 14	Jupiter and his	7 09 35	Im.	B.	4th satellite.
"	satellites	7 10 42	Im.	B.	West limb of Jupiter.
"	"	7 12 15	Im.	B.	East " "
"	"	7 15 29	Im.	B.	1st satellite.
"	"	8 20 52	Em.	B.	West limb of Jupiter.
"	"	8 22 06	Em.	B.	East " "
1821, Aug. 26	Solar eclipse	22 30 13	End	B.	Place of observation 1 s. E. of Observatory.
1823, July 22	Lunar eclipse	8 51 30	Beg.	B.	
"	"	9 58 30		B.	Beginning of total obscuration.
1824, June 26	Solar eclipse	7 27 59	Beg.	B.	
Oct. 25	Unknown star	6 09 33	Im.	B.	
1825, July 27	o Sagittarii	7 33 22	Im.	B.	
"	"	8 19 56	Em.	B.	
"	π Sagittarii	11 04 01	Im.	B.	
Aug. 8	Aldebaran	15 25 49	Im.	B.	
"	"	16 39 53	Em.		
"	* Tauri	15 42 15	Im.	B.	
1826, March 15	Saturn	10 49 57	Em.	B.	Centre.

Date.	Name of Star.	Mean Solar Time of Occultation. h.	m.	s.		Obser-ver.	Remarks.
1827, Feb. 10	2 α Cancri	7	19	54.0	Im.	B.	
Nov. 16	Spica	0	17	24.0	Im.	B.	About noon. Star distinct.
Nov. 28	ε Piscium	5	19	03.2	Im.	B.	
1828, Jan. 31	1 α Cancri	6	40	39.4	Im.	B.	
Aug. 16	λ Virginis	7	22	43.6	Em.	B.	
1829, Aug. 21	Aldebaran	11	58	54.5	Im.	B.	
"	"	13	51	37.5	Em.	B.	
Sept. 12	Lunar eclipse	12	32	15.	Beg.	B.	
"	Tycho	12	51	40.		B.	Total obscuration of centre.
Sept. 17	Aldebaran	21	19	33.6	Im.	B.	
"	"	22	19	49.0	Em.	B.	Doubtful.
Sept. 23	o Leonis	16	19	57.8	Im.	B.	
"	"	16	56	36.8	Em.	B.	
Nov. 11	Aldebaran	17	06	35.5	Im.	B.	
"	"	17	46	57.5	Em.	B.	
1830, Jan. 5	* Tauri	5	46	50.0	Im.	B.	Instantaneous on the ☽'s dark [limb.
"	* "	6	57	16.	Em.	B.	Uncertain 10 s.
"	* "	6	05	57.	Im.	B.	10′ south of ☽'s centre.
"	160 Mayer	7	08	01.	Im.	B.	Near the ☽'s south limb.
"	α Tauri	10	14	51.0	Im.	B.	Exact.
"	"	11	12	50.	Em.	B.	Not well observed.
March 12	κ Virginis	11	33	00.	Im.	B.	A poor observation.
March 28	Aldebaran	5	06	01.0	Im.	B.	The Em. particularly fine, the star [was projected on the ☽'s disk.
"	"	6	19	51.0	Em.	B.	
July 15	"	17	33	37.0	Im.	B.	
Sept. 2	Lunar eclipse	6	55	30.	Em.	B.	Aristarchus.
"	"	7	07	00.	Em.	B.	Tycho.
"	"	7	20	15.	Em.	B.	Manilius.
"	"	7	44	15.	Em.	B.	Moon's west limb.
Oct. 4	*f* Tauri	9	44	01.0	Im.	B.	
"	"	10	07	33.0	Em.	B.	
1831, Jan. 21	μ^1 Ceti	5	54	54.6	Im.	B.	
Feb. 4	γ Libra	17	38	05.9	Im.	B.	
"	"	19	03	13.0	Em.	B.	Star is faint.
Feb. $\frac{11}{12}$	Eclipse of sun	23	50	12.3	Beg.	B.	
"	North cusp	0	13	34.2		B.	Meridian observations inst. az. 5″ [west of south.
"	☽'s east limb	0	12	41.2		B.	First wire.
"	"	0	14	15.2		B.	Middle wire.
"	"	0	15	49.7		B.	Third wire.
"	Sun's centre	0	14	39.2		B.	From transit of east limb.
"	South cusp	0	14	12.0		B.	By one passage over first wire.
Feb. 13	Venus	1	43	56.0	Im.	B.	Im. of centre. ☽ is not visible in [the telescope.
"	"	1	44	19.0	Im.	B.	Total Im.
Feb. 19	θ^1 Tauri	7	31	16.1	Im.	B.	

Date.	Name of Star.	Mean Solar Time of Occultation. h.	m.	s.		Observer.	Remarks.
1831, Feb. 19	ϑ^1 Tauri	8	44	04.6	Em.	B.	Appeared good, but the star was quite clear of the ☽'s limb.
"	ϑ^2 Tauri	7	40	44.6	Im.	B.	
"	"	8	36	11.	Em.	B.	Uncertain several seconds.
"	* Tauri	7	49	44.6	Im.	B.	Exact.
"	* "	8	26	13.6	Im.	B.	Exact.
"	* "	8	42	00.6	Im.	B.	Exact. Star is of the same brilliancy as ϑ^1 and ϑ^2 Tauri.
"	* "	8	47	41.	Im.	B.	Uncertain three or four seconds. Star very faint.
"	Aldebaran	11	43	37.0	Im.	B.	Good.
Feb. 28	γ^1 Virginis	8	31	00.2	Em.	B.	
Aug. 28	*f* Tauri	16	19	12.0	Im.	B.	
"	"	17	17	20.0	Em.	B.	Dubious.
Aug. 29	γ Tauri	11	55	55.8	Im.	B.	Good.
"	"	12	43	41.8	Em.	B.	"
"	Aldebaran	20	28	19.2	Im.	B.	Very fine. A slight projection.
"	ϑ^1 Tauri	16	10	09.0	Im.	B.	
"	ϑ^2 Tauri	16	29	43.0	Im.	B.	
"	"	16	49	24.0	Em.	B.	Among the mountains of ☽'s S. limb.
Oct. 14	π Capricorni	8	09	57.0	Im.	B.	Star tremulous on ☽'s dark limb.
Oct. 21	μ^1 Ceti	11	21	44.0	Im.	B.	Difficult to keep sight of the star.
Oct. 23	Aldebaran	7	28	58.2	Im.	B.	Lingered two or three seconds on the ☽'s limb.
"	"	8	16	34.0	Em.	B.	Exact.
Dec. 15	μ^1 Ceti	9	41	22.4	Im. ?	B.	
1832, Feb. 16	Saturn	13	12	37.9	Im.	B.	First contact of the ring.
"	"	13	12	55.9	Im.	B.	" " west limb.
"	"	13	13	23.4	Im.	B.	Total Im.
"	"	14	29	23.0	Em.	B.	Ring first seen.
"	"	14	30	36.0	Em.	B.	Body of the planet appears distorted, though the ring is well defined.
June 17	δ Capricorni	14	16	09.5	Im.	B.	Projected from the ☽'s limb for five seconds.
"	"	14	58	58.3	Em.	B.	
July 28	Solar eclipse	7	17	07.1	Beg.	B.	
"	"	9	00	19.3	End	B.	
Sept. 7	δ Capricorni	8	49	04.2	Im.	B.	
"	"	9	59	14.8	Em.	B.	
1834, March 13	* unknown	7	45	32.0	Im.	B.	The star is brighter at the last moment.
1836, May 15	Solar eclipse	7	25	36.0	Beg.	B.	
"	"	9	59	56.6	End	B.	
"	"	7	25	34.5	Beg.	W.	
1837, Feb. 18	Mars	5	02	27.6	Im.	B.	1st Limb. Telescope used is a 5-ft.
"	"	5	03	16.1	Im.	B.	2d " Reflector, 7-in. ap.
"	"	5	24	07.6	Em.	B.	1st "
"	"	5	25	02.6	Em.	B.	2d "
"	"	5	03	03.3	Im.	W.	Centre. 30-in. reflector.
"	"	5	24	42.3	Em.	W.	Centre.
Aug. 10	Antares	10	34	40.3	Im.	B.	Not instantaneous.

Date.	Name of Star.	Mean Solar Time of Occultation.				Observer.	Remarks.
		h.	m.	s.			
1837, Sept. 13	ψ^1 Aquarii	8	08	26.2	Im.	B.	Stars are both very faint. Uncertain 5 s.
"	ψ^2 "	8	51	06.9	Im.	B.	
Oct. 13	Lunar eclipse	5	51	25.	Beg.	B.	Total obscuration.
"	"	7	18	25.	End	B.	" "
"	*1 Piscium	6	38	06.6	Im.	B.	
"	*2 "	6	40	34.0	Im.	B.	
"	*1 "	7	15	35.2	Em.	B.	
"	*2 "	7	15	35.2	Em.	B.	
"	*3 "	7	03	29.2	Im.	B.	
1838, Sept. 18	Solar eclipse	3	28	10.9	Beg.	B.	The occultations of several spots were observed.
Nov. 5	C. Geminorum	9	10	20.7	Em.	B.	Very indifferent. ☽ is low.
Nov. 13	Spica	8	32	38.4	Im.	B.	Slightly projected.
Dec. 27	η Tauri	2	51	53 *	Im.	B.	* Sidereal time.
1839, April 19	C. Geminorum	8	20	31.9	Im.	B.	
"	"	8	20	32.0	Im.	W.	
April 20	ν Geminorum	10	44	24.6	Im.	B.	
"	"	10	44	24.4	Im.	W.	
June 19	28 Virginis	8	14	31.0	Im.	B.	Occulted by a mountain. 2d Im. 8h. 16m. 11.2 s.
June 20	68 Virginis	8	23	15.0	Im.	B.	A double Im., interval 0.2 s.
June 23	b Virginis	9	15	45.4	Im.	B.	Fine.
July 1	φ Aquarii	13	57	51.7	Im.	B.	
"	"	15	10	33.4	Em.	B.	Fine.
July 6	C. Pleiadum	16	13	32.5	Im.	B.	Pretty good, on the north edge of the ☽.
Sept. 11	τ Scorpii	6	42	15.0	Im.	W.	
Nov. 20	b Pleiadum	6	40	03.4	Im.	B.	
"	c 1 "	7	15	09.1	Im.	B.	
"	η "	7	46	27.4	Im.	B.	Projected.
Dec. 12	λ Aquarii	8	39	04.7	Im.	B.	Good.

OCCULTATIONS AND ECLIPSES,

Observed at Cambridge. Lat. 42° 22′ 22″. Lon. $4^{h.}$ $44^{m.}$ $30^{s.}$ W.

Date.	Name of Star.	Mean Solar Time of Occultation. h. m. s.		Obser-ver.	Remarks.
1840, Jan. 20	α Leonis	9 44 31.7	Em.	B.	
July 10	τ Scorpii	10 23 45.8	Im.	W.	
"	"	10 23 46.4	Im.	B.	
Oct. 6	*d* Capricorni	8 58 41.1	Im.	B.	
"	"	8 58 43.2	Im.	W.	Observed with a telescope by Plöpl.
Oct. 13	* Pleiadum	7 06 34.2	Im.	B.	
"	* "	7 16 24.9	Em.	B.	
"	* "	7 33 45.7	Em.	B.	
Nov. 2	ι Capricorni	6 51 36.7	Im.	B.	
"	"	6 51 36.9	Im.	W.	
Dec. 14	76 Leonis	15 56 13.2	Em.	B.	Doubtful.
1842, Jan. 21	* Tauri	6 41 04.6	Im.	B.	The stars are of the 8th or 9th mag.
"	* "	6 55 26.0	Im.	B.	Differing 12s. in A. R.
April 12	ε Arietis	7 17 19.6	Im.	B.	
June 20	Antares	8 37 01.4	Em.	B.	
1843, Jan. 24	σ Scorpii	18 06 29.3	Em.	B.	
"	"	18 06 29.6	Em.	B.[2]	
April 2	ε Arietis	7 31 35.0	Im.	B.	
Aug. 12	κ Piscium?	8 01 25.4	Em.	B.	Doubtful.
Sept. 30	39 Sagittarii	9 06 49.5	Im.	B.	
Nov. 3	45 Piscium	8 37 47.6	Im.	B.	
Nov. 24	104 Piscium	13 06 15.6	Im.	B.	Uncertainty in the reduction.
Dec. 11	*b* Leonis	10 33 26.5	Em.	B.	
1844, Feb. 22	104 Piscium	7 13 23.2	Im.	B.	Appeared within the ☽'s border.
May 23	19 Sextantis	9 50 32.1	Im.	B.	
Aug. 28	* unknown	14 04 05.8	Em.	B.	
Sept. 4	105 Tauri	11 06 47.6	Em.	B.	

OCCULTATIONS AND ECLIPSES,

Observed at Cambridge Observatory. Lat. 42° 22′ 49″. Lon. 4h. 44m. 32s.

Date.	Name of Star.	Mean Solar Time of Occultation. h. m. s.		Obser-ver.	Remarks.
1844, Sept. 19	2150 A. S. C.	9 03 37.7	Im.	B.	
"	"	9 03 37.8	Im.	B.2	
Nov. 18	8 Piscium	9 04 40.5	Im.	B.	
"	"	9 04 40.0	Im.	B.2	
Nov. 24	51 Tauri	6 50 23.5	Im.	B.	During the lunar eclipse.
"	"	7 56 32.4	Em.	B.	" "
Dec. 9	Solar eclipse	3 45 36.0	Beg.	B.	
"	"	3 45 38.2	Beg.	B.2	
Dec. 14	51 Aquarii	9 28 21.8	Im.	B.	
"	"	9 28 20.6	Im.	B.2	
1845, Jan. 26	87 Leonis	18 43 30.4	Em.	B.	
March 1	2033 A. S. C.	15 53 39.3	Em.	B.	
"	"	15 53 39.4	Em.	B.2	
April 11	666 A. S. C.	10 33 04.9	Im.	B.	
May 5	Eclipse of sun	17 18 02.2	End		By Hon. Wm. Mitchell.
"	"	17 18 04.2	End	B.2	Uncertain, perhaps, 5 s. Sun's altitude 3°. Atmosphere clear, but disturbed.
"	"	17 18 04.3	End	B.	
July 16	58 Sagittarii	9 34 00.9	Im.	B.	
"	"	9 34 00.4	Im.	B.2	
July 17	29 Sagittarii	10 11 29.1	Im.	B.	
"	"	10 11 29.1	Im.	B.2	
Sept. 15	18 Piscium	7 09 53.0	Im.	B.	
Sept. 22	57 Orionis	11 26 24.1	Em.	B.	
"	"	11 26 21.3	Em.	B.2	Good.
"	64 Orionis	16 23 48.2	Em.	B.	"
"	"	16 23 45.7	Em.	B.2	"
Oct. 23	60 Cancri	12 42 29.8	Em.	B.	"
Nov. 10	63 Piscium	5 43 06.0	Im.	B.	Well.
"	"	5 43 05.2	Im.	B.2	
Nov. 20	2 Leonis	18 08 16.7	Em.	B.	
Dec. 6	22 Piscium	10 31 29.8	Im.	B.	
"	"	10 31 29.0	Im.	B.2	
1846, Jan. 13	60 Cancri	10 53 49.1	Em.	B.2	
Feb. 4	74 Tauri	7 05 57.9	Im.	B.	
Feb. 6	71 Orionis	9 08 00.5	Im.	B.	
"	"	9 08 00.3	Im.	B.2	
Feb. 20	16 Sagittarii	17 20 28.3	Em.	B.2	
"	"	17 20 27.4	Em.	B.	
"	17 Sagittarii	17 31 45.7	Em.	B.	

Date.	Name of Star.	Mean Solar Time of Occultation. h. m. s.		Obser-ver.	Remarks.
1846, March 29	Jupiter	5 23 34.5	Im.	B.	First contact.*
"	"	5 24 43.5	Im.	B.	Second "
"	"	5 24 44.1	Im.	B.[2]	" "
"	"	6 33 54.2	Em.	B.	Third "
"	"	6 34 58.8	Em.	B.	Fourth "
"	"	6 33 53.3	Em.	B.[2]	Third "
"	"	6 35 04.7	Em.	B.[2]	Fourth "
"	Preced. Satell.	6 32 41.7	Em.	B.[2]	
"	Follow. Satell.	6 38 42.1	Em.	B.	
March 31	97 Tauri	10 43 09.1	Im.	B.	
"	"	10 43 08.7	Im.	B.[2]	
April 24	Solar eclipse	23 14 17.2	Beg.	B.	5-ft. refractor.
"	"	20.7	Beg.	B.[2]	46-inch refractor.
"	"	26.8	Beg.		R. T. Paine, reflector, 4-in. aper.
"	"	35.2	Beg.		Prof. Peirce, 20-in. Var. Transit.
April 25	Solar eclipse	1 52 23.0	End		" "
"	"	14.6	End	B.	
"	"	12.0	End	B.[2]	
"	"	09.1	End		R. T. Paine.
May 3	2 Leonis	8 54 02.9	Im.	B.	
"	"	8 54 02.9	Im.	B.[2]	
June 29	69 Leonis	8 26 57.9	Im.	B.	
"	"	8 26 58.0	Im.	B.[2]	

* The first contact was evinced by a sudden flattening of the limb of the planet. At the Emersion, one observer noted an elongation of the body of the planet in the direction of the moon's limb, and both saw distinctly a rectangular indentation on that part of the moon's border which was in contact with the limb of the planet.

IV.

An Account of the Nebula in Andromeda.

By GEORGE P. BOND,
ASSISTANT AT THE CAMBRIDGE OBSERVATORY.

(*Read before the Academy, March 7th*, 1848.)

Of the four thousand nebulæ which have been recognized, that which forms the subject of the present account is the only one the discovery of which preceded the invention of the telescope. The evidence which history affords of its having been noticed prior to the year 1612 is derived through Ismael Bouillaud, a writer of the seventeenth century, author of the *Philolaica Astronomica*, and, among other astronomical treatises, of one entitled, *De Nebulosâ in Andromeda Cinguli Parte Boreâ ante Biennium iterum Ortû;* containing an ancient catalogue of stars, with charts of the constellations, on which the nebula is represented of an oval form, and according to Le Gentil, "fait un angle avec le circle de longitude." By comparing the positions of the stars in this catalogue with modern determinations, the latter found that the date of its construction was towards the close of the tenth century. As there seems to be no reason for doubting the authenticity of this production, it is probable that the great nebula in Andromeda was recognized at least six hundred years before the invention of the telescope.

Its appearance in 1612 is described with some care by Simon

Marius in the Preface to his *Mundus Jovialis.* It was then visible to the naked eye, and appeared through the telescope to be composed of rays of light (*radii albicantes*), increasing in brightness as they approached the centre, which was marked by a dull, pale light, — " in centro est lumen obtusum et pallidum." Its diameter was a quarter of a degree, and it resembled the light of a candle, at some distance, shining through horn. Its appearance is also compared to that of the comet observed by Tycho Brahe in 1586.* From some of his remarks, it seems that this author regarded the nebula as an object of extraordinary interest; and he expresses his astonishment at its having been unnoticed by Tycho when observing the stars in its neighbourhood.

No further intimation of its having been seen is to be found until 1664. In that year, the appearance of a comet having directed the attention of astronomers to the region in the vicinity of the nebula, it was again discovered, and has not since been lost sight of.

In the treatise of Ismael Bouillaud before referred to, which was published in 1667, the author maintains, from the fact of its not having been recorded either by Hipparchus, Tycho, or Bayer, as well as from what he had himself observed, that this nebula is subject to periodical variations in brightness; an opinion which was maintained by many during the succeeding century.

In 1740, Cassini defines its figure as nearly triangular. Mairan, after stating that the description given by Simon Marius conformed to what he had himself observed in 1754, asserts that it is subject to changes. The same views are supported by Le Gentil in a memoir, *Sur les Étoiles Nebuleuses.* From a careful

* As there was no comet in 1586, that of 1585 is perhaps intended.

review of its past history, he concludes that the periodical variations of the nebula extend to its figure, as well as to its brightness. His grounds for this conclusion may be briefly stated as follows: —

1. The nebula is not found in any of the ancient catalogues.

2. It was visible to the naked eye in the year 995, and its form was then oval.

3. For more than six hundred years afterwards it was unnoticed.

4. The description given by Simon Marius of its appearance in 1662 does not accord, in an important particular, — that of exhibiting a central condensation, — with the observations of Le Gentil in 1750.

5. This condensation was not mentioned by Bouillaud in 1666, who records an evident change of brilliancy between 1664 and 1666.

6. Cassini, in 1740, represents its figure as triangular.

7. Mairan, in 1754, regards the representation of Simon Marius as essentially correct.

8. His own observations indicated a round figure, of uniform density throughout, in 1749; and an oval figure with a central condensation, in 1757–8.

Although expressing himself convinced, by the foregoing considerations, of the reality of a change, Le Gentil at the same time suggests that these phenomena may be, in part, at least, explained by referring them to the difference in the instrumental means employed by the several observers. His own telescopes were the common refractors, of from three to thirty feet in focal distance, in use before the invention of the achromatic object-glass, and were of course very inferior to instruments of a more recent date.

As all subsequent accounts of this nebula can, without violence,

be reconciled with its appearance at the present day, it may reasonably be concluded that the views of Le Gentil, with regard to its variability, are far from being supported by an amount of evidence adequate to such a conclusion. Messier, in 1771, remarks, that for fifteen years he had noticed no change in the nebula; it always appeared to him bright at the centre, the light fading away insensibly towards both extremities, its figure resembling that of two cones with their bases opposed. In the *Philosophical Transactions* for 1785, it is thus described by Sir William Herschel.

"It is undoubtedly the nearest of all the great nebulæ; its extent is about a degree and one half in length, and, in even one of the narrowest places, not less than sixteen minutes in breadth. The brightest part of it approaches to the resolvable nebulosity, and begins to show a faint red color; which, from many observations on the color and magnitude of nebulæ, I believe to be an indication that its distance in its colored parts does not exceed two thousand times the distance of Sirius.

"There is a very considerable, broad, pretty faint, small nebula near it; my sister discovered it, August 27th, 1783, with a Newtonian two-feet sweeper. It shows the same faint color with the great one, and is, no doubt, in the neighbourhood of it. It is not the 32d of the *Connaissance des Temps*; which is a pretty large, round nebula, much condensed in the middle, and south-following the great one; but this is about two thirds of a degree north-preceding it, in a line parallel to β and γ Andromedæ."

In the same memoir from which the above extract is taken occurs the following passage.

"But it is nevertheless very evident that the united lustre of millions of stars, such as I suppose the nebula in Andromeda to be, will reach our sight in the shape of a very small, faint nebulosity; since the nebula of which I speak may easily be seen in a fine evening."

It ought, perhaps, here to be observed, that the views of this illustrious astronomer, in later years, received some modification in respect to the nature of many of the nebulæ.

The following is Sir John Herschel's description, in 1826.

"At present it has not, indeed, a star, or any well-defined disk in its centre, but the brightness, which increases by a regular gradation from the circumference, suddenly acquires a great accession, so as to offer the appearance of a nipple as it were in the middle, of very small diameter (10″ or 12″), but totally devoid of any distinct outline; so that it is impossible to say precisely where the nucleus ends and the nebula begins.

"Its nebulosity is of the most perfectly milky absolutely irresolvable kind, without the slightest tendency to that separation into flocculi above described in the nebula in Orion, nor is there any sort of appearance of the smallest star in the centre of the nipple. This nebula is oval, very bright, and of great magnitude, and altogether a most magnificent object."

The following passage, occurring in another connection, may also be cited.

"The great nebula in Andromeda may be, and not improbably is, optically nebulous, owing to the *smallness* of its constituent stars."

In 1836, Dr. Lamont, of Munich, observed it with a refractor of great capacity; under a power of 1200, the diameter of the nucleus was about 7″. His description accords with that of Sir John Herschel.

The mounting of the great refractor of the Cambridge Observatory having been completed in the beginning of July, 1847, an early opportunity was taken of directing it upon the nebula in Andromeda, as being an object of prominent interest; and from that time, through the month of August, it was occasionally viewed, though without particular attention. The most con-

spicuous features were the sudden condensation of light at the centre into an almost starlike nucleus; the vast number of stars, of every gradation of brilliancy, scattered over its surface, which yet had the undefinable, but still convincing, aspect of not being its components; and, lastly, what appeared to be a sudden termination of the light on the side of the nebula preceding in right ascension.

But it was not until the beginning of the autumn that a careful examination was commenced of the regions of the nebula remote from the nucleus. On the 14th of September, a favorable opportunity offered for further investigation. By directing the attention to the preceding portion of the nebula, as it passed the centre of the field of view, it was evident that what had hitherto been regarded as its boundary in that direction was rather a sudden interruption of light, appearing like a narrow, dark band, in which the eye could detect no deviation from perfect straightness, stretching, in the direction of the axis of the nebula, entirely across the field of vision; exterior to this, with respect to the axis, was another band or canal, closely resembling the former, but somewhat less distinct, of equal regularity, and so nearly parallel with it as to make it difficult to decide, by simple inspection, whether they were not perfectly so. What particularly commands admiration here is the regularity of structure displayed, — the uniform influence, made manifest to the senses, of the same law over an immensity of space of which the mind can form no adequate conception; since the distance at which Sir William Herschel places this nebula requires that the length of the interior canal should not be estimated at less than twenty times the distance of Sirius from our system.

As a groundwork for the delineation of the principal features

of this nebula, it was at first proposed to prepare, from micrometric measurements, a map of the principal stars involved in the light. But their great number,* and the consequent danger of confusion, having rendered this impracticable, the circle readings of the equatorial were resorted to for the determination of all the positions referred to in this memoir.

The extent of the region to be examined being from fifteen to twenty times larger than could be included within a single field of the telescope, the brightest portions, namely, from Dec. 39° 40′ to Dec. 41° 10′, were divided into eighteen sections, each comprising five minutes of declination, and extending in right ascension across the nebula. The telescope was clamped in declination at the middle of each zone, and the examination was commenced by moving the instrument with a quick motion in right ascension, which was found necessary in order to determine with any certainty the limit of light on either side of the axis. The nebula was then allowed to pass through the field by its diurnal motion, and the times recorded when the different gradations of light occupied the centre of the field, taking in each transit, for the standard of brilliancy, that portion of the axis intersected by the zone ; the hour-circle was then read off, and the instrument set for a new series. The different zones were finally referred to a common unit of brightness, by a cross section from the nucleus to both extremities of the axis. In this manner an idea, though not a very accurate one, was obtained of the situation of the lines of equal brilliancy. The observations were then charted, so as to present them at a single view, accompanied by such remarks as had been recorded at the time at

* It is estimated that above fifteen hundred stars are visible with the full aperture of the object-glass within the limits of the nebula.

which they were made. The chart thus constructed was used as a guide in attempting the delineation of the nebula.

The figure which accompanies this memoir is necessarily on much too small a scale to admit of the introduction of minute details. Though prepared with care, in the manner just described, it must remain open to future correction. The chief source of error has been the difficulty of referring every portion to the same standard of brightness.

The observations generally were made under very favorable circumstances. In a large proportion, the altitude of the nebula exceeded seventy degrees; in more than one instance, its zenith distance was less than two degrees. Those nights only were employed in which the moon was absent, and the sky perfectly clear. The power usually employed was one hundred and three, with a field of twenty minutes. The following are the results of the examination to which the nebula has been subjected.

The nucleus is nearly centrally situated with respect to the general body of light, but perhaps nearest the side following in right ascension. Its appearance cannot be better described than by adopting the words of Sir John Herschel already quoted.

With high powers, minute stars are discerned on the borders of the nucleus, but it has thus far yielded no evidence of resolution. About fifty stars are visible in the same field with it; no other equal space occurs within the limits of the nebula containing so few.

The region south-preceding the nucleus is somewhat brighter than the opposite side; this has been noticed by Smyth; it is also so represented on Harding's Atlas, whether by accident or designedly does not appear. The axis of the nebula, which is for the most part strongly marked, particularly in its south-preceding half,

lies in a great circle passing near the nucleus. In some places, not in the immediate vicinity of the nucleus, its resemblance to the milky way, as it appears to the naked eye, both as to its structure and in the number and disposition of the stars in it, is such, that the comparison conveys a tolerably correct idea of its appearance when seen under the most favorable circumstances.

The justice of this comparison received some additional confirmation on counting the number of stars visible in different fields of view. It was thought that, in the richest regions, two hundred to a single field was not an extravagant estimate.

The power employed being one hundred and three, having a field of view of twenty minutes, the *apparent* field subtended an angle of about thirty-four degrees. The portion of the milky way included in a circle of the same dimensions described about α Cygni contains about two hundred and ten stars, visible without telescopic aid. It should be noticed that the presence of these stars is no safe indication of resolution, since there is equal reason for supposing that we are viewing the nebula through a dense stellar stratum, which would produce the same impression on the eye.

The nebula *h* 51 is involved in the light of the great nebula. *h* 44 appears, under high powers, to be a coarse cluster of stars, the direction of the axis being determined apparently by three somewhat brighter than their companions; there is little doubt of a connection with the great nebula, by a continuation of the axis of *h* 44 in the south-following direction.

h 45, which is registered as "a very large space filled with nebulous matter," is far within the limits of the great nebula. No. 7 of the catalogue of "Extensive Diffused Nebulosities," published by Sir William Herschel in the *Philosophical Transactions* for 1811, is also a part of the great nebula.

No. 8 of the same catalogue lies so near to the southern boundary of the nebula, that, according to the dimensions assigned to it, it should also be considered as connected.

The most interesting feature of the nebula is the existence of the dark bands or canals before referred to. That which is nearest the nucleus is the longest and the most distinct. It commences somewhat abruptly near a group of small stars, in A. R. $0^{h.}\ 32^{m.}\ 36^{s.}$ and Dec. $40^{\circ}\ 07'$; its breadth being about one minute and one half of arc. For about half a degree, to A. R. $0^{h.}\ 34^{m.}\ 10^{s.}$, Dec. $40^{\circ}\ 30'$, it is marked with great uniformity; its sides being to all appearance perfectly straight, suddenly terminated, and slightly diverging. Soon after passing the parallel of the nucleus, it appears to bend towards the following side, becoming fainter and less regular; beyond the parallel of $40^{\circ}\ 50'$ it can no longer be traced with certainty.

The second commences at a point a few minutes north-preceding the first, and is there distant from it about four minutes of arc. It closely resembles its companion, excepting that, as it occurs in fainter light, it is less distinct, and is sooner lost after passing the nucleus.

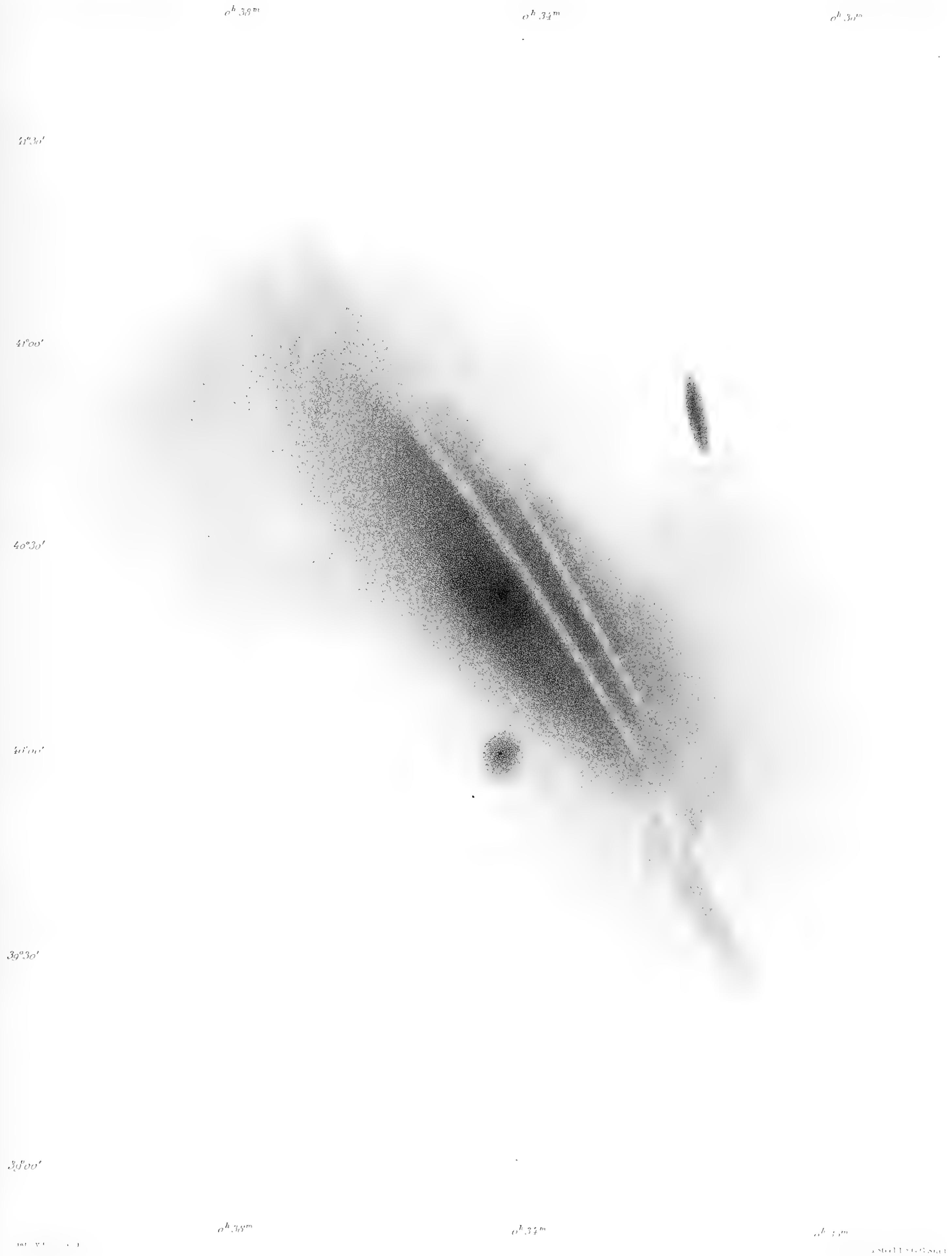
The two are inclined to each other by an angle of about three degrees, their distance apart increasing towards the north. Their sides seem to have a common point of divergence.

Sir John Herschel, in his catalogue of nebulæ published in the *Philosophical Transactions* for 1833, refers, with an expression of astonishment, to a structure evidently analogous to that just described, though on a scale greatly inferior, which occurs in *h* 1357 and 1376; engravings of both, faithfully representing the originals, accompany the catalogue. It may be noticed that these three most interesting objects lie almost precisely in a great circle of right ascension, which intersects the milky way at right angles.

The following table contains the right ascension and declination of the chief points of interest in the nebula. It should be observed, that, where the light is faint, the positions given are liable to a considerable degree of uncertainty.

	A.R. 1850.	Dec. 1850.	Remarks.
	h. m. s.	° ′	
1	0 30 50	+39 17	The axis may be traced to this point.
2	0 31 30	39 27	Light blends with the star-dust which fills the field; the axis is about 5′ broad and not distinguishable without attention.
3	0 31 55	39 38	Axis suddenly widens and becomes brighter.
4	0 32 12	39 45	Light brighter and unequally diffused, with dark openings; many stars in clusters.
5	0 32 08	39 55	Suddenly much brighter. The peculiarity noticed in 4 is more strongly marked. The position given is that of a spot much brighter than any other part of the field.
6	0 32 15	39 58	Axis 12′ broad and distinctly marked. The light is more evenly diffused, brighter and more nebulous in its character, especially on the following side.
7	0 34 30	40 00	Companion nebula *h* 51. It is certainly within the light of the great nebula; in the field preceding it are multitudes of very small stars, on a ground of very evenly diffused, milky nebulosity.
8	0 32 36	40 07	Southern extremity of the inner canal.
9	0 31 40	40 10	Light is here unequally diffused. On the side following the axis, it falls away more rapidly than on that preceding.
10	0 33 40	40 15	The northern part of the field is brightest. Both canals are well seen in this parallel. The light is shaded off from them evenly on the preceding side.
11	0 33 15	40 20	Both canals beautifully distinct. The light between them is two thirds as bright as it is on the inner side of that which is nearest to the nucleus. Both large and small stars are very abundant in this parallel.

	A.R. 1850.	Dec. 1850.	Remarks.
	h. m. s.	° ′	
12	0 34 24	+40 26	The nucleus. The light shades off soonest on the following side.
13	0 35 00	40 36	The light is here broken up and unequal; with numerous stars. The canals in this parallel begin to incline towards the following side.
14	0 32 00	40 36	Apparent continuation of *h* 44 in the south-following direction towards the great nebula.
15	0 36 40	40 36	A dark opening in the surrounding nebulosity. In and north of this parallel, the light is distributed with less regularity than heretofore; and the outer canal is frequently interrupted.
16	0 35 40	40 50	The inner canal is not to be traced with certainty beyond this point.
17	0 34 36	40 53	Stars very numerous. The light shades off more gradually on the side following the axis than it does nearer the nucleus.
18	0 35 50	40 57	A ridge of light, or of stars, parallel to the axis, gives the impression of a continuation of the inner canal. Many small stars.
19	0 35 11	41 03	Light in decided bright knots, with dark openings, as in 4 and 5. Great numbers of stars. This is the position of *h* 45; there is no uncertainty with regard to its being a part of the great nebula.
20	0 38 12	41 20	Northern extremity of the axis.



THE GREAT NEBULA IN ANDROMEDA, 1847.

V.

Description of the Nebula about the Star θ Orionis.

By W. C. BOND,

DIRECTOR OF THE CAMBRIDGE OBSERVATORY.

(*Read before the Academy, April* 3, 1848.)

THE nebula surrounding the star θ Orionis was first seen, figured, and described by Huygens in 1659. During nearly two hundred years it has continued to excite the interest of astronomers, while every successive improvement in the telescope has developed some new and remarkable feature.

It was the first object to which Sir William Herschel directed his noble forty-foot reflector, in 1787, and it subsequently engaged much of his attention. To his distinguished son we are indebted for the first delineation which could be called even an approximation to its true figure.

The drawings and the description of this nebula, which Sir John Herschel has given to the public in the second volume of the Memoirs of the Royal Astronomical Society of London, were founded principally upon observations made with his twenty-foot reflectors during the years 1824–26. Every one joined with him, at that time, in the opinion that he had given a sufficiently accurate representation to serve as a standard of comparison for subsequent observers in regard to change of form or condition.

The utmost care and skill had been devoted to the work, in order to locate the stars justly, and to give all the different degrees of intensity and convolutions of the light with precision and delicacy. Nevertheless, the first glance which Sir John Herschel obtained of it under the more favorable auspices for observation which he enjoyed ten years afterwards, during his residence at the Cape of Good Hope, sufficed to convince him of the necessity of executing a re-delineation. This improved drawing, accompanied by a catalogue of the stars situated within the boundaries of the nebulosity, as well as a general description, have been embodied in *The Results of Astronomical Observations made at the Cape of Good Hope during the Years* 1834–38, and published in 1847.

Other observers, as Derham, Godin, Fouchy, Mairan, Picard, Le Gentil, Messier, De Vico, Lassell, Mitchell, and Lamont, have given us the results of their observations on this interesting object. The earlier observations have little value, owing to the deficiency in optical power of the instruments used. As Sir John Herschel's publication embraces nearly every important point connected with the subject which was known at that time, and is founded upon the observations of so many years, made with excellent telescopes, under favorable circumstances, it will be the one principally referred to in this communication; his nomenclature also will be adhered to, as it possesses the advantage of being already well known.

For the purpose of obtaining a general knowledge of the region in which the great nebula of Orion is situated, I commenced my operations by making a cursory examination of about four square degrees of the heavens in the neighbourhood of θ Orionis.

This examination developed the more prominent features, and enabled me to fix upon a convenient scale for the intended drawing. A system of sweeps was then instituted after the following manner. The telescope, being clamped in declination, was carried forward until it preceded the utmost limits of the nebula. It was then fixed in right ascension, and the successive fields carefully examined as they passed in review by the diurnal movement of the heavens. The different degrees of intensity of the light were indicated by numbers. Thus, when the first nebulous appearance reached the middle of the field of view of the telescope, the time was noted by a sidereal chronometer, and the degree of light, representing the faintest perception of light, was recorded as 7. When an increase of light was discernible, the time was again noted, and the figure 6, indicating a confirmation, was recorded; this has been adopted generally for the outline of the nebulous district. 5 shows a yet further increase of light. In this way, the different portions included in a single sweep were examined, 1 indicating the strongest light, in the vicinity of the Trapezium.

When it was judged that the whole nebulosity had passed, the hour-angle and declination circles were read off, the declination-circle changed five minutes, and the examination of another parallel commenced. The results of these sweeps were then reduced to right ascension and declination by differentiating on θ^1 Orionis, and, being corrected for convergence, were finally transferred to a chart, and are embodied in the drawings which accompany this memoir.

These sweeps were extended from half a degree north of the star C Orionis to one degree south of the star ι, θ^1 being constantly referred to as the point of departure.

This general method, however, would not answer for delineating the more delicate and intricate portions; for this purpose, as well as for the accurate location of the stars, it became necessary to have recourse to the micrometer. With this instrument, such stars as appeared to be favorably situated were arranged in groups by an eye sketch. The star θ^1 being adopted in the first instance as a primary station, differences of right ascension and declination, or of position and distance, were measured: when the distances became excessive, new stations were occupied, taking care always to preserve the connection with the preceding point by repeated measures.

A catalogue of the stars thus differentiated accompanies the memoir. No attempt has been made to locate every star that was visible within the boundaries of the nebula, for the reason that no apparent advantage, at all adequate to the great expenditure of time and labor which it would have required, was to be expected.

In order to obtain a correct outline of the more important points in the figure of the nebula, the stars contained in the annexed catalogue were, in the first instance, laid down according to their observed differences of right ascension and declination. All such parts of the nebula in the vicinity of the Trapezium as presented definite outlines susceptible of being measured were referred to θ^1. Guided by these points, the outline was drawn and filled in, after many repeated examinations of the object under different powers.

In the course of these examinations with different eye-pieces, I was struck with a remarkable diversity in the appearance of the Huygenian region. It seems, as we increase the power of our eye-piece, that the clouds or clusters into which this region

separates become less numerous, in a manner quite different from that which would result from viewing it under a greater angle merely. The clusters increase in magnitude, while they diminish in number. Sir John Herschel, when describing this portion, as seen at Slough with his twenty-foot reflector, compares its appearance to that of "a curdling liquid, or the mottling of the sun's disk, only the grain is much coarser and the intervals darker." To me it appears composed of several clusters of stars, the components being separately seen for a moment under favorable circumstances. This resolution I have noticed more particularly north of star No. 26, and likewise in the vicinity of No. 12 and No. 43; but where the nebula assumes a cirrous character, as in the Messierian branch, I can see nothing of the kind.

There is quite a remarkable feature of the subnebulous region, which I do not find has been noticed heretofore. It is that of radiation, spreading and shooting southward from the stars Nos. 45, 50, and 61, near its base. I have noticed this appearance only on clear nights, when the moon has been absent, but then, on several occasions, it was very decided, and forcibly reminded me of an active aurora borealis.

There is something of the same character belonging to the light on the preceding side of the Huygenian region, but not so delicate; it is there more abrupt.

The Messierian branch, although extremely well defined, and presenting a bold outline on the preceding side from star No. 30 to No. 61, yet thence to its junction with the brightest portion of the nebula it presents no certain outline on either side, but fades insensibly into the Proboscis Minor on the one side and into the subnebulous region on the other. I mention this more particularly, because Sir John Herschel's last drawing exhibits a

regular, well-defined outline all the way to its junction with the Huygenian region; in this particular, I see it more like his early drawing of 1824.

On the preceding side of the Huygenian region, there is a strongly marked boundary, reaching nearly the whole distance from its southern extremity to star No. 10. This boundary was confirmed to me on the night of the 17th of January, while the moon was shining brightly in the immediate neighbourhood of the nebula. On comparing the sketch which I then made of it with the ancient figures of Picard, Huygens, and Le Gentil, they appeared less objectionable than one would have supposed possible without such a trial.

The Nebula Oblongata, which lies entirely south of a line joining the stars No. 76 and No. 93, divides on the following side into two branches. One of these branches curves towards, and apparently terminates near, the star No. 93; the other inclines southward, and connects with the Proboscis Minor. In the preceding direction, it can be traced to a junction with the nebula encircling the star No. 60.

The stars Nos. 10, 12, 26, and 27 mark the present boundaries of the Huygenian region, on the preceding and following sides, very accurately. Provided they are not physically connected with the nebula, they will serve as excellent landmarks for future comparison in regard to any change of form or position, should it take place.

No. 10 is situated close on the preceding edge of this bright region, and is closely followed almost in the same parallel by No. 12, a star of the seventeenth magnitude, the latter being *within* the boundary.

No. 27 is, as nearly as it is possible to determine with our

telescope, on the very edge of the following side, at the bottom of the Sinus Magnus, and is pretty closely preceded by No. 26, of the seventeenth magnitude, within the bright part. I do not find that star No. 27 has been noticed before; but when once caught sight of, there will be no great difficulty in judging of its situation in regard to the nebula, as it may be steadily seen. No. 27 will bear illuminated wires.

There is a great diminution of light in the interior of the Trapezium, but no suspicion of a star.

The connection of the main body of the nebula with that portion which surrounds C^1 Orionis is traced by the north-preceding route. It is quite decided; the nebulous light condenses strongly about C^1 and C^2; indeed, the majority of the stars in this neighbourhood are nebulous. C^1 is closely double: this, I believe, has not been noticed before.

No. 68 is also to me a new double star, the distance less than a second. The light terminates abruptly on the following side of C^2. The star No. 54, with its companion No. 52, of the thirteenth magnitude, are both enveloped by the nebula. I notice that, in Sir John Herschel's figure, the light does not reach either of these two stars.

There is nebulous light yet farther north; but as, at the time, I did not succeed in tracing the connection, I have not included it in my drawings; neither does the light of C Orionis connect on the following side with the extensive fields about No. 92.

South of the double star No. 91, which is situated near the termination of the Messierian branch, the light spreads in the south-preceding direction, maintaining the cirrous character of the branch. I was unable to satisfy myself how far it might be possible to trace it southward, but certainly beyond Iota. Soon after passing this star, it, however, becomes very faint.

The small star No. 69 I do not find to have been noticed. No. 34 is also, I think, a new addition; it follows No. 81 of Herschel's Cape Catalogue.

I do not find that No. 44 of the nineteenth magnitude has been seen before; it is situated in a brilliant district, and is a difficult object to keep steadily in view; it follows No. 41 at a distance of about six seconds; the direction of a line joining these two stars is towards *a* of the Trapezium.

Sir John Herschel's drawing shows the southern termination of the Huygenian region strongly preceding *a*, whereas I have repeatedly laid the micrometer-wire upon it, and have found it to be of the same right ascension as *a*. The difference of declination between this point and *a* is 161″.

His star No. 75 is well seen, but No. 78, to which the same magnitude is given in his table, has not been seen steadily by me. Indeed, the observations on it at different times have been so contradictory, that I could only account for the discrepancies by supposing it to be a variable star of short period.

In respect to the evidence of change in this nebula, the following points seem to demand attention.

In the first place, the regular, graceful, and well-defined outlines, indicated in Sir John Herschel's figure, both of the Messierian branch and that from the Huygenian region, sweeping along north of the stars Nos. 45–50 and 61 of my catalogue, certainly do not exist at present; or, I should rather say, I have not been able to trace them with our telescope at times when I could distinctly see stars that had escaped his notice. The outline of the Messierian branch cannot be distinguished below the star No. 61, while the bright portion of the Huygenian region ter-

minates abruptly and roughly at No. 50, and the nebula immediately assumes a totally different and a milder character.

Again, on the preceding side of the Messierian branch, near No. 75 of my catalogue, I do not find so bold an indenture as he has given. It is in this neighbourhood only that I have found any difficulty in identifying his stars. I presume that I have here two new stars, but neither No. 75, nor the two next south of it, agrees in position with any of the stars in his catalogue.

The preceding side of the Huygenian region in his figure has the light gradually softened away into the "Regio Gentiliana." I here see a strong irregular outline, extending from the "Sinus Gentilii" to a little beyond No. 10.

The positions of the stars marked with an asterisk, in the annexed catalogue, were determined by alignment only, from stars in their neighbourhood which had been subjected to micrometrical measurement. This approximate method was considered sufficiently accurate in this case, as the stars in question were, from their situation, of minor importance in regard to the principal object which I had in view, namely, a true delineation of the nebula.

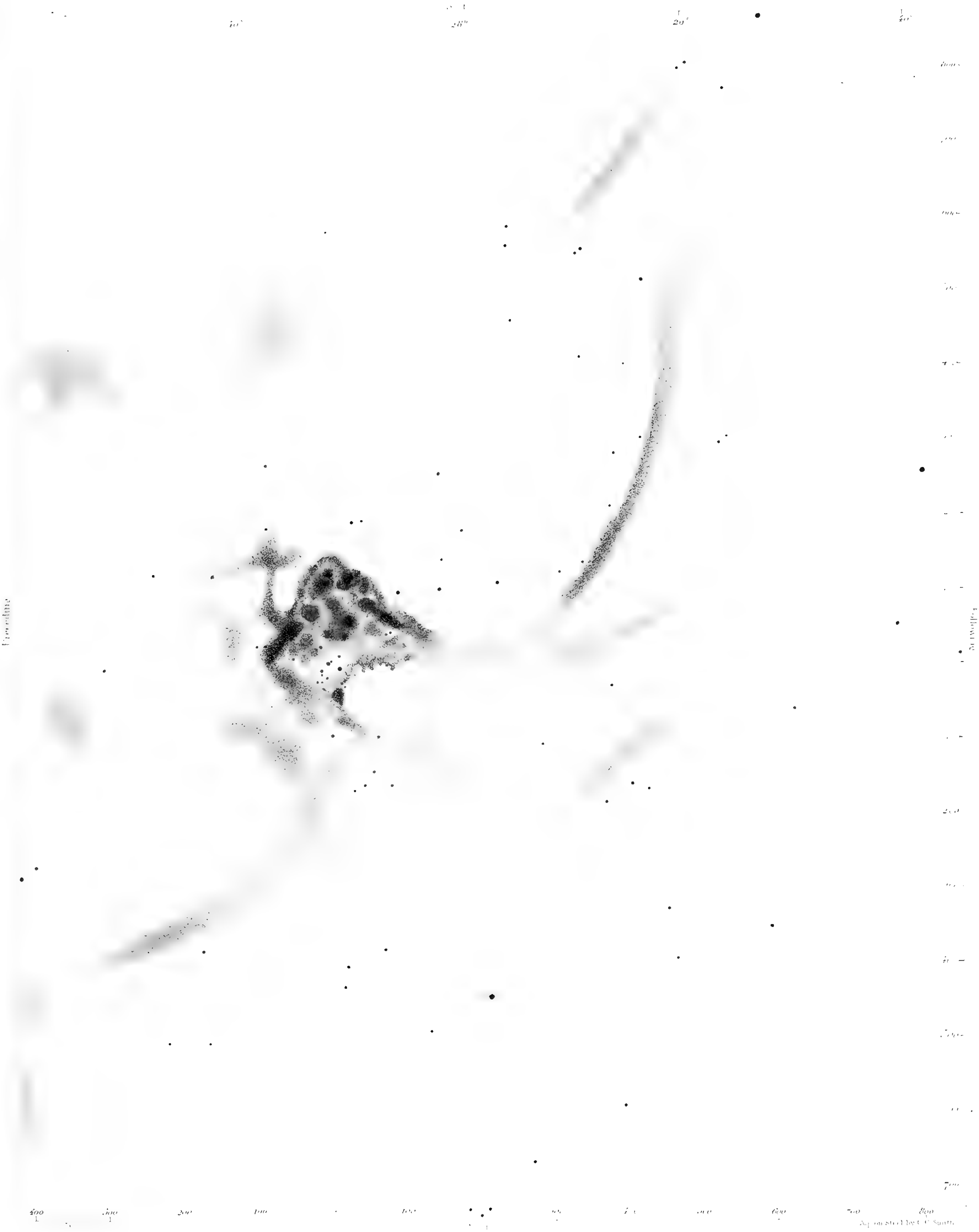
In this catalogue the stars are numbered in the order of their right ascensions, and are all referred, in seconds and decimals of seconds, of arc, to θ^1 (No. 22) of the Trapezium.

In the column headed x, — signifies that the star precedes, and + that it follows θ^1, by so many seconds, measured in the direction of AR.

In the column headed y, + signifies that the star has greater, and — that it has less, north polar distance than θ^1.

CATALOGUE OF STARS OBSERVED IN THE NEBULA ABOUT Θ ORIONIS.

No.	Mag.	x.	y.	No.	Mag.	x.	y.
1	11	− 499.3	− 289.4	49	13	+ 148.9	+ 251.8
2	14	− 463.5	+ 114.5	50	8	+ 150.5	+ 95.8
3	10	− 400.2	− 271.3	51	12	+ 150.9	+ 134.7
4	10	− 306.7	− 5.3	*52	13	+ 155.	− 1698.
5	11	− 242.3	+ 118.0	53	14	+ 156.3	− 1897.9
6	10	− 219.0	− 510.1	54	4	+ 171.0	+ 1869.9
7	11	− 173.4	− 385.2	55		+ 180.2	+ 175.4
8	12	− 164.1	− 513.0	56	15	+ 190.0	− 731.1
9	15	− 159.4	+ 120.1	57	8	+ 194.8	− 1747.4
10	17	− 101.0	+ 23.6	58	15	+ 200.0	− 736.0
11	18	− 90.2	+ 22.6	59	15	+ 208.0	− 730.2
12	17	− 88.0	+ 181.0	60	8	+ 215.6	− 446.4
13	9	− 87.1	+ 273.4	61	10	+ 227.3	+ 111.7
14	11	− 71.3	− 1897.6	62	8	+ 226.7	− 1985.4
15	18	− 52.0	+ 5.0	*63	11	+ 235.	+ 565.
*16	19	− 12.	− 22.	*64	11	+ 243.	+ 585.
17	7	− 9.3	− 8.4	65	12	+ 244.7	+ 464.0
18	18	− 7.0	+ 13.8	66	9	+ 277.4	− 669.9
*19	19	− 6.	− 19.	67	19	+ 285.2	− 109.0
*20	20	− 5.	− 27.	68	12	+ 304.6	− 2101.0
21	8	− 4.8	− 15.2	69	18	+ 308.8	+ 123.6
22	5	0.0	0.0	70	7	+ 320.4	− 1927.3
23	14	+ 5.1	− 98.0	71	12	+ 335.1	+ 411.3
*24	18	+ 9.	+ 8.	72	12	+ 338.2	+ 557.6
25	7	+ 12.6	− 6.1	73	17	+ 340.2	+ 135.4
26	17	+ 15.7	− 25.5	74	10	+ 340.2	+ 560.6
27	18	+ 17.2	− 27.5	75	17	+ 375.4	+ 213.3
28	14	+ 20.5	− 433.0	76	10	+ 373.3	− 195.3
29	13	+ 26.3	− 407.5	77		+ 378.3	− 66.3
30	17	+ 27.5	+ 190.2	78	18	+ 385.4	+ 282.6
*31	19	+ 29.	− 11.	79	9	+ 405.0	− 596.0
32	17	+ 30.3	− 169.7	80	12	+ 423.8	+ 523.8
33	15	+ 35.7	− 160.4	81	14	+ 461.6	+ 793.8
34	18	+ 37.3	+ 192.3	82	12	+ 465.0	− 391.7
35	13	+ 48.1	− 1806.9	83	17	+ 455.9	− 331.4
36	10	+ 48.5	− 1894.4	84	14	+ 475.4	+ 799.8
37	15	+ 55.8	− 147.3	85	12	+ 424.4	− 168.6
38	12	+ 61.0	− 675.2	86	16	+ 414.7	+ 306.8
39	14	+ 62.1	− 98.8	87	12	+ 520.4	+ 302.8
40	7	+ 72.6	− 1989.0	*88	16	+ 527.	+ 771.
41	17	+ 73.5	+ 36.8	*89	18	+ 531.	+ 307.
42		+ 75.5	− 383.9	*90	11	+ 547.	− 2126.
43	18	+ 76.5	+ 38.0	91	8	+ 581.3	+ 876.3
*44	19	+ 80.	+ 40.	92	15	+ 596.6	− 355.8
45	6	+ 97.5	+ 94.4	93	10	+ 630.2	− 58.8
46	11	+ 125.9	− 2152.8	94	13	+ 800.3	+ 258.4
47	9	+ 140.5	− 494.7	95	9	+ 1061.8	+ 56.8
48	10	+ 143.7	− 614.1	96	13	+ 1136.4	+ 9.0



THE NEBULA SURROUNDING THE STAR THETA ORIONIS

As seen with the Twenty three feet Refractor at Cambridge U.S. 1848

VI.

Some Methods of Computing the Ratio of the Distances of a Comet from the Earth.

By GEORGE P. BOND,

ASSISTANT AT THE CAMBRIDGE OBSERVATORY.

(*Communicated to the Academy, April* 4, 1848.)

THE object of the following communication is to present some methods of computing the ratio of the distances of a comet from the earth from three observed positions, separated by short intervals of time, in which, if required, the computations may be made (1)
directly from right ascensions and declinations.

If necessary, any unfavorable influence from the direction, relatively to the sun, of the comet's apparent motion may be avoided, and account may be taken of parallax at the outset of the calculations.

The frequent references made to Dr. Bowditch's Appendix to his translation of the *Mécanique Céleste* are denoted by the letter B. prefixed; thus, B. [5994] (357) refers to the equation so numbered on p. 821 of the Appendix.

I. If we denote by $[r\,r']$, $[r'\,r'']$, and $[r\,r'']$ double the areas of the triangles included between the three distances r, r', and r'' of the comet from the sun at the first, second, and third observations, and the chords joining their extremities, and by z, z', and z'' its elevations above any fixed plane passing through the sun, we have

the following well-known relation, B. [5994] (266) to (279), depending on the supposition that r, r', and r'' lie in the same plane:

(2) $$0 = [r'\, r'']\, z - [r\, r'']\, z' + [r\, r']\, z''.$$

Representing by ϱ, θ, and α, R, Θ, and $\odot$, the polar coördinates
(2a) of the comet and sun from the place of the first observation, and accenting the same quantities for the second and third places, ϱ, R, &c., being the distances of the comet and sun respectively,
(3) and substituting $z = \varrho \sin.\, \theta - R \sin.\, \Theta$ in (2), it becomes

(4) $$0 = \frac{[r'\, r'']}{[r\, r']}\, \varrho \sin.\, \theta - \frac{[r\, r'']}{[r\, r']}\, \varrho' \sin.\, \theta' + \varrho'' \sin.\, \theta'' - \frac{[r'\, r'']}{[r\, r']}\, R \sin.\, \Theta + \frac{[r\, r'']}{[r\, r']}\, R' \sin.\, \Theta' - R'' \sin.\, \Theta''.$$

Making $\frac{[r'\, r'']}{[r\, r']} = \frac{[R'\, R'']}{[R\, R']} + \varDelta$, and $\frac{[r\, r'']}{[r\, r']} = \frac{[R\, R'']}{[R\, R']} + \varDelta'$, and supposing R, R', and R'' to lie in the same plane, the last three terms of (4) are reduced to two by B. [5994] (362); and (4) becomes

(5) $$0 = \frac{[r'\, r'']}{[r\, r']}\, \varrho \sin.\, \theta - \frac{[r'\, r'']}{[r\, r']}\, \varrho' \sin.\, \theta' + \varrho'' \sin.\, \theta'' - \varDelta\, R \sin.\, \Theta + \varDelta'\, R' \sin.\, \Theta'.$$

If t, t', and t'' denote the times for which α, α', and α'', &c., are
(6) given, and $\tau = k\, (t'' - t')$, $\tau' = k\, (t'' - t)$, $\tau'' = k\, (t' - t)$, in which $\log.\, k = 8.2355814$, B. [5994] (319) to (360), we have, by neglecting the powers of τ, &c., above the second:

(7) $$\frac{[r'\, r'']}{[r\, r']} = \frac{\tau}{\tau''} \left[1 - \frac{1}{6 r'^3} (\tau^2 - \tau''^2) + \&c.\right], \quad \frac{[r\, r'']}{[r\, r']} = \frac{\tau'}{\tau''} \left[1 - \frac{1}{6 r'^3} (\tau'^2 - \tau''^2) + \&c.\right]$$

(8) $$\varDelta = \frac{\tau}{\tau''} \cdot \frac{1}{6} (\tau^2 - \tau''^2) \left(\frac{1}{R'^3} - \frac{1}{r'^3}\right) +, \&c., \text{and } \varDelta' = \frac{\tau'}{\tau''} \cdot \frac{1}{6} (\tau'^2 - \tau''^2) \left(\frac{1}{R'^3} - \frac{1}{r'^3}\right) + \&c.$$

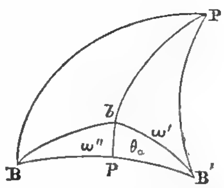
τ^2, τ'^2, &c., are supposed (1) to be small quantities of the second
(9) order; therefore $\frac{[r'\, r'']}{[r\, r']} = \frac{\tau}{\tau''}$ and $\frac{[r\, r'']}{[r\, r']} = \frac{\tau'}{\tau''}$ may be assumed as approximate values.

(10) By putting the angles θ, θ', &c., in (4) successively, either separately or in pairs $= 0$, that is, by changing the position of the plane of z (2), any term of (4), or any two together, can be made to disappear. But since the expressions thus derived from (4) will contain angles referred, in each equation, to a separate system of

coördinates, the following method may be applied to refer them all to the system to which the original values of α, θ, &c. ($2a$) belong.

Let P be the pole of this system, and let A and D, A' and D', be the angles corresponding to α and θ, by which are referred to P the two points B and B', determining the position of (11)
the plane in (10) from which the transformations are to be made.

$PB = 90° - D$, $PB' = 90° - D'$, $BPb = \sigma - A$, $BPB' = A' - A$, $B'Pb = A' - \sigma$, $bp = \theta_0 =$ the perpendicular from b upon BB'; $bP = 90° - \varpi$, $Bb = \omega$, $bB'B = \Omega$, &c.: we are to find an expression for sin. θ_0, for any position of the point b, in terms of A, A', D, D', σ and ϖ, observing that sin. θ_0 may have any coefficient which remains constant in all positions of b, because this will disappear when sin. θ_0 is introduced into (4).



We have sin. $\theta_0 =$ sin. ω' sin. Ω, and by multiplying both sides (12)
of this equation by sin ω'', it becomes

$$\sin.\ \theta_0\ \sin.\ \omega'' = \sin.\ \omega'\ \sin.\ \omega''\ \sin.\ \Omega.$$

$$\sin.^2\theta_0\ \sin.^2\omega'' = \sin.^2\omega'\ \sin.^2\omega''\ \sin.^2\Omega = (1-\cos.^2\omega')\,(1-\cos.^2\omega'')\,(1-\cos.^2\Omega).$$

Substituting in the last member $\cos.\ \Omega = \frac{\cos.\ \omega - \cos.\ \omega'\ \cos.\ \omega''}{\sin.\ \omega'\ \sin.\ \omega''}$, (12) becomes

$$\sin.^2\theta_0\ \sin.^2\omega'' = 1 + 2\cos.\ \omega\ \cos.\ \omega'\ \cos.\ \omega'' - \cos.^2\omega - \cos.^2\omega' - \cos.^2\omega''. \quad (12a)$$

$$\cos.\ \omega = \sin.\ D\ \sin.\ \varpi + \cos.\ D\ \cos.\ \omega\ \cos.\ (\sigma - A),\ \cos.\ \omega' = \sin.\ D'\ \sin.\ \varpi + \cos.\ D'\ \cos.\ \varpi\ \cos.\ (A' - \sigma),\ \cos.\ \omega'' = \sin.\ D\ \sin.\ D' + \cos.\ D\ \cos.\ D'\ \cos.\ (A' - A).$$

These values of cos. ω, cos. ω', and cos. ω'' being substituted in ($12a$), it becomes, after reduction (see Memoirs of the Berlin Academy, for 1783, p. 308 *et seq.*),

$$\sin.\ \theta_0\ \sin.\ \omega'' = [\sin.\ (A' - \sigma)\ \tan.\ D - \sin.\ (A' - A)\ \tan.\ \varpi + \sin.\ (\sigma - A)\ \tan.\ D']\ \cos.\ D\ \cos.\ D'\ \cos.\ \varpi\,;$$

by means of which equation (4) becomes, by substituting successively the proper values of ϖ and σ,

(13) $0 = [\sin.(A'-\alpha)\tan.D-\sin.(A'-A)\tan.\theta+\sin.(\alpha-A)\tan.D']\frac{[r'r'']}{[rr']}\varrho\cos.\theta$
$-[\sin.(A'-\alpha')\tan.D-\sin.(A'-A)\tan.\theta'+\sin.(\alpha'-A)\tan.D']\frac{[rr'']}{[rr']}\varrho'\cos.\theta'$
$+[\sin.(A'-\alpha'')\tan.D-\sin.(A'-A)\tan.\theta''+\sin.(\alpha''-A)\tan.D']\varrho''\cos.\theta''$
$-[\sin.(A'-\odot)\tan.D-\sin.(A'-A)\tan.\Theta+\sin.(\odot-A)\tan.D']\frac{[r'r'']}{[rr']}R\cos.\Theta$
$+[\sin.(A'-\odot')\tan.D-\sin.(A'-A)\tan.\Theta'+\sin.(\odot'-A)\tan.D']\frac{[rr'']}{[rr']}R'\cos.\Theta'$
$-[\sin.(A'-\odot'')\tan.D-\sin.(A'-A)\tan.\Theta''+\sin.(\odot''-A)\tan.D']R''\cos.\Theta''.$

(13a) The sum of the last three terms being by (5) and (8) of the second order in τ.

(14) By introducing in (13) the proper values of the arbitrary quantities A, A', D, and D', we can obtain all the equations which can be derived from (4), by (10), in a form in which right ascensions and declinations may be employed directly in the computations, but not always with advantage over the simpler expressions of (10), except in those approximations in which the effect of parallax, and the quantities Δ and Δ' are neglected; because the
(15) angles θ, θ', &c., in the equations derived directly by (10) from (4) have a definite geometrical meaning, which is an advantage in computation.

(16) Putting θ' and Θ' in (4) and (5) $= 0$, they become

(17) $$0 = \frac{[r'r'']}{[rr']}\varrho\sin.\theta + \varrho''\sin.\theta'' - \frac{[r'r'']}{[rr']}R\sin.\Theta - R''\sin.\Theta''.$$

(18) $$0 = \frac{[r'r'']}{[rr']}\varrho\sin.\theta + \varrho''\sin.\theta'' - \Delta R\sin.\Theta.$$

(19) θ, Θ, &c., being here perpendiculars upon the great circle joining the middle places of the sun and comet.

(17) and (18) may be expressed in terms of the original values of θ and α, &c., by taking in (13) for the points B and B' (11) the places of the sun and comet at the second observation, that is, $A = \alpha'$, $D = \theta'$, $A' = \odot'$, $D' = \Theta'$, which give

(20) $0 = [\sin.(\odot'-\alpha)\tan.\theta'-\sin.(\odot'-\alpha')\tan.\theta+\sin.(\alpha-\alpha')\tan.\Theta']\frac{[r'r'']}{[rr']}\varrho\cos.\theta$
$+[\sin.(\odot'-\alpha'')\tan.\theta'-\sin.(\odot'-\alpha')\tan.\theta''+\sin(\alpha''-\alpha')\tan.\Theta']\varrho''\cos.\theta''$
$-[\sin.(\odot'-\odot)\tan.\theta'-\sin.(\odot'-\alpha')\tan.\Theta+\sin.(\odot-\alpha')\tan.\Theta']\frac{[r'r'']}{[rr']}R\cos.\Theta$
$-[\sin.(\odot'-\odot'')\tan.\theta'-\sin.(\odot'-\alpha')\tan.\Theta''+\sin.(\odot''-\alpha')\tan.\Theta']R''\cos.\Theta''.$

The sum of the last two terms is by (5) and (8), when τ and τ'' are nearly equal, of the third order in τ. If they are neglected, (20) gives

$$\frac{\varrho'' \cos. \theta''}{\varrho \cos. \theta} = \frac{\tau}{\tau''} \frac{\sin. (\odot' - \alpha) \tan. \theta' - \sin. (\odot' - \alpha') \tan. \theta + \sin. (\alpha - \alpha') \tan. \Theta'}{\sin. (\odot' - \alpha') \tan. \theta'' - \sin. (\odot' - \alpha'') \tan. \theta' + \sin. (\alpha' - \alpha'') \tan. \Theta'} + \qquad (21)$$

terms of the third order in τ when $\tau = \tau''$.

If we put $\Theta' = 0$, that is, supposing α, θ, &c., to represent longitudes and latitudes, (21) becomes identical with Olber's equation for determining the ratio of the curtate distances of a comet from the earth, at the first and last observations; (21) is therefore (22)
this equation adapted to direct computation from right ascensions and declinations. The same values neglected give, from (18), $\frac{\rho''}{\rho} = -\frac{\tau}{\tau''} \frac{\sin. \theta}{\sin. \theta''}$, θ and θ'' having the signification stated in (19). (23)
It follows from (23), that in practice the accuracy of (17), (20), (24)
and (21) will be proportional to the sine of the angle which the direction of the comet's apparent motion makes with the great circle joining the places of the sun and comet at the second observation.

When this angle is small, the terms neglected in (21) and (23), (25)
and errors of observation, acquire an important influence. The best position is when the comet is near the ecliptic at the middle observation, and its motion is mostly in latitude. The equation (20), on which the method of Olbers depends, has the peculiar advantage of eliminating $\frac{[r r'']}{[r r']}$, of which the approximate value (9) is less (26)
accurate than that of $\frac{[r' r'']}{[r r']}$, which is retained.

If the motion of the comet is mostly in right ascension, the (27)
following equations may be employed, which result from substituting in (13) $A' = A = \alpha'$, $D' = 0$, and $A' = A = \alpha''$, $D' = 0$:

$$0 = \sin. (\alpha' - \alpha) \frac{[r' r'']}{[r r']} \varrho \cos. \theta + \sin. (\alpha' - \alpha'') \varrho'' \cos. \theta'' - \sin. (\alpha' - \odot) \frac{[r' r'']}{[r r']} \qquad (28)$$
$$R \cos. \Theta + \sin. (\alpha' - \odot') \frac{[r r'']}{[r r']} R' \cos. \Theta' - \sin. (\alpha' - \odot'') R'' \cos. \Theta''.$$

(29) $$0 = \sin.\,(\alpha'' - \alpha)\,\frac{[r'\,r'']}{[r\,r']}\,\varrho\,\cos.\,\theta - \sin.\,(\alpha'' - \alpha')\,\frac{[r\,r'']}{[r\,r']}\,\varrho'\,\cos.\,\theta' - \sin.\,(\alpha'' - \odot)\,\frac{[r'\,r'']}{[r\,r']}\,R\,\cos.\,\Theta + \sin.\,(\alpha'' - \odot')\,\frac{[r\,r'']}{[r\,r']}\,R'\,\cos.\,\Theta' - \sin.\,(\alpha'' - \odot'')\,R''\,\cos.\,\Theta''.$$

In which α, θ, &c., represent right ascensions and declinations.

(30) Since the accuracy of the ratios $\frac{\rho''}{\rho}$, or $\frac{\rho'}{\rho}$, on which may be made to depend that of the resulting elements, will, under similar conditions, be proportional to the sine of the angle which the direction of the comet's apparent path makes with the great circle $B\,B'$ (11), as may readily be shown; the best position of this circle is that which is nearly perpendicular to the direction of
(31) motion. This condition is satisfied by putting in (28), θ and $\theta'' = 0$, and giving to α, $\odot$, &c., their proper significations;
(32) sin. $(\alpha' - \odot)$ cos. Θ, &c., will then represent the sines of the perpendiculars from the sun's places, upon the great circle passing through the middle observation, which is nearly perpendicular
(33) to the direction of the comet's motion. $\alpha' - \alpha$ and $\alpha' - \alpha''$ will then comprise the whole amount of the comet's motion in the intervals between the observations, and consequently, by the con-
(34) ditions, the coefficients of ϱ and ϱ'' are as accurate as the observations will give, and are independent of the direction of the comet's path.

(35) The same result is obtained by putting in (4), θ' or $\theta'' = 0$, and giving to θ, Θ, &c., their significations as just stated (32).

(36) $$0 = \frac{[r'\,r'']}{[r\,r']}\,\varrho\,\sin.\,\theta + \varrho''\,\sin.\,\theta'' - \frac{[r'\,r'']}{[r\,r']}\,R\,\sin.\,\Theta + \frac{[r\,r'']}{[r\,r']}\,R'\,\sin.\,\Theta' - R''\,\sin.\,\Theta''.$$

(37) $$0 = \frac{[r'\,r'']}{[r\,r']}\,\varrho\,\sin.\,\theta - \frac{[r\,r'']}{[r\,r']}\,\varrho'\,\sin.\,\theta' - \frac{[r'\,r'']}{[r\,r']}\,R\,\sin.\,\Theta + \frac{[r\,r'']}{[r\,r']}\,R'\,\sin.\,\Theta' - R''\,\sin.\,\Theta''.$$

(38) The sum of the last three terms being of the second order in τ (13 a).

These may be expressed in terms of right ascension and dec-
(39) lination as follows: — Let C represent the right ascension of a point in the equator, the great circle from which passes through

the middle place of the comet, at nearly right angles with its path. A change of twenty or thirty degrees in the position of C having (40) seldom much influence, it may be taken of a convenient value for computation in (41), (42). Substituting in (13) $A'=C$, $D'=0$, $A=\alpha'$, and $D=\theta'$, it becomes,

$$0=[\sin.(C-\alpha)\tan.\theta'-\sin.(C-\alpha')\tan.\theta]\frac{[r'r'']}{[rr']}\varrho\cos.\theta+[\sin.(C-\alpha'')\tan.\theta' -\sin.(C-\alpha')\tan.\theta'']\varrho''\cos.\theta''-[\sin.(C-\odot)\tan.\theta'-\sin.(C-\alpha')\tan.\Theta]\frac{[r'r'']}{[rr']}R\cos.\Theta+[\sin.(C-\odot')\tan.\theta'-\sin.(C-\alpha')\tan.\Theta']\frac{[rr'']}{[rr']}R'\cos.\Theta' -[\sin.(C-\odot'')\tan.\theta'-\sin.(C-\alpha')\tan.\Theta'']R''\cos.\Theta''. \quad (41)$$

And in a similar manner is found,

$$0=[\sin.(C-\alpha)\tan.\theta''-\sin.(C-\alpha'')\tan.\theta]\frac{[r'r'']}{[rr']}\varrho\cos.\theta-[\sin.(C-\alpha')\tan.\theta''-\sin.(C-\alpha'')\tan.\theta']\frac{[rr'']}{[rr']}\varrho'\cos.\theta'-[\sin.(C-\odot)\tan.\theta''-\sin.(C-\alpha'')\tan.\Theta]\frac{[r'r'']}{[rr']}R\cos.\Theta+[\sin.(C-\odot')\tan.\theta''-\sin.(C-\alpha'')\tan.\Theta']\frac{[rr'']}{[rr']}R'\cos.\Theta'-[\sin.(C-\odot'')\tan.\theta''-\sin.(C-\alpha'')\tan.\Theta'']R''\cos.\Theta''. \quad (42)$$

As C in these equations is an arbitrary quantity, they may be made (43) to satisfy other conditions, as $C=0$; this value gives from (41),

$$0=\left[\sin.\alpha-\frac{\sin.\alpha'}{\tan.\theta'}\tan.\theta\right]\frac{[r'r'']}{[rr']}\varrho\cos.\theta+\left[\sin.\alpha''-\frac{\sin.\alpha'}{\tan.\theta'}\tan.\theta''\right]\varrho''\cos.\theta''-\left[\sin.\odot-\frac{\sin.\alpha'}{\tan.\theta'}\tan.\Theta\right]\frac{[r'r'']}{[rr']}R\cos.\Theta+\left[\sin.\odot'-\frac{\sin.\alpha'}{\tan.\theta'}\tan.\Theta'\right]\frac{[rr'']}{[rr']}R'\cos.\Theta'-\left[\sin.\odot''-\frac{\sin.\alpha'}{\tan.\theta'}\tan.\Theta''\right]R''\cos.\Theta''. \quad (44)$$

Neglecting the sum of the last three terms of (36), it becomes, using (9), $-\frac{\rho''}{\rho}=\frac{\tau}{\tau''}\frac{\sin.\theta}{\sin.\theta''}$. In which θ and θ'' represent, nearly, (45) the apparent motion of the comet during the intervals τ'' and τ. Hence, in small intervals of time, the distance of a comet from the earth varies nearly inversely as its apparent motion. When, therefore, its motion is mostly in right ascension or declination, this relation gives a rough approximation to the ratio of the distances ϱ, ϱ', and ϱ''.

In all the equations here given, except those which contain the quantities $\varDelta$ and $\varDelta'$, allowance for parallax may be made at the (46)

outset by correcting the tabular places of the sun for parallax
(47) and by applying to R, R', and R'' a small correction $=$ — earth's radius $\times$ cosine of the sun's zenith distance at the time of each
(48) observation. By neglecting terms of the second order in either of the above equations, approximate values are obtained of the ratios $\frac{\rho''}{\rho}$ or $\frac{\rho'}{\rho}$, which will be more or less accurate according as the assumed values of $\frac{[r'r'']}{[rr']}$ and $\frac{[rr'']}{[rr']}$ vary from the true.

II. For the correction of these latter quantities different methods may be employed, in the several cases which may occur;
(49) in all of which the object in view is to obtain from the use of erroneous values new values, which shall be nearer the truth than those from which they have been derived; the convergence of the successive approximations depending on the amount of heliocentric motion in the intervals between the observations.

Using in (4) $\theta' = \theta'' = 0$,

(50) $$0 = \frac{[r'r'']}{[rr']}\,\varrho \text{ sin. } \theta - \frac{[r'r'']}{[rr']}\,R \text{ sin. } \Theta + \frac{[rr'']}{[rr']} \text{ sin. } \Theta' - R'' \text{ sin. } \Theta''.$$

(51) $$0 = \frac{[r'r'']}{[rr']}\,\varrho \text{ sin. } \theta - \varDelta\, R \text{ sin. } \Theta + \varDelta'\, R' \text{ sin. } \Theta'.$$

And in a similar manner,

(52) $$0 = -\frac{[rr'']}{[rr']}\,\varrho' \text{ sin. } \theta' - \frac{[r'r'']}{[rr']}\,R \text{ sin. } \Theta + \frac{[rr'']}{[rr']}\,R' \text{ sin. } \Theta' - R'' \text{ sin. } \Theta''.$$

(53) $$0 = -\frac{[rr'']}{[rr']}\,\varrho' \text{ sin. } \theta' - \varDelta\, R \text{ sin. } \Theta + \varDelta'\, R' \text{ sin. } \Theta'.$$

(54) $$0 = \varrho'' \text{ sin. } \theta'' - \frac{[r'r'']}{[rr']}\,R \text{ sin. } \Theta + \frac{[rr'']}{[rr']}\,R' \text{ sin. } \Theta' - R'' \text{ sin. } \Theta''.$$

(55) $$0 = \varrho'' \text{ sin. } \theta'' - \varDelta\, R \text{ sin. } \Theta + \varDelta'\, R' \text{ sin. } \Theta'.$$

These may be expressed in terms of right ascension and dec-
(56) lination. As, for instance, putting in (13), $A = \alpha$, $D = \theta$, $A = \alpha''$, and $D' = \theta''$; or denoting by C' the right ascension of the point in the equator, where it is intersected by the great circle passing through the first and last places of the comet, and putting in (13), $A = \alpha$, $D = \theta$, $A' = C'$, $D' = 0$:

$$0 = -[\sin.(C' - \alpha') - \frac{\sin.(C' - \alpha)}{\tan.\theta} \tan.\theta'] \frac{[r r'']}{[r r']} \varrho' \cos.\theta' - [\sin.(C' - \odot) - \frac{\sin.(C' - \alpha)}{\tan.\theta} \tan.\Theta] \frac{[r' r'']}{[r r']} R \cos.\Theta + [\sin.(C' - \odot') - \frac{\sin.(C' - \alpha)}{\tan.\theta} \tan.\Theta'] \frac{[r r'']}{[r r']} R' \cos.\Theta' - [\sin.(C' - \odot'') - \frac{\sin.(C' - \alpha)}{\tan.\theta} \tan.\Theta''] R'' \cos.\Theta''. \quad (57)$$

In which α, θ, &c., represent right ascensions and declinations. But the original forms are perhaps to be preferred. It is to be observed that C' is not here arbitrary, as C is in (41), (42), (43).

From these equations it is evident, that, when $\frac{[r'r'']}{[rr']}$ and $\frac{[rr'']}{[rr']}$ are known, ϱ, ϱ', or ϱ'' may be found; also, that θ, θ', and θ'', in (58)
the coefficients of ϱ, ϱ', and ϱ'', which represent the deviation of the path of the comet from the arc of a great circle, are of the same order with Δ and Δ', or of the second order, generally, in τ, but affected by the whole amount of the error of the observed places. There is still, however, even when the coefficients of ϱ, ϱ', and ϱ'' are $= 0$, a relation to be sustained between $\frac{[r'r'']}{[rr']}$ and $\frac{[rr'']}{[rr']}$, which (59)
may be made use of in correcting their assumed values (9), (48). Excepting the case when the path of the comet is in the ecliptic; (50), (52), and (54) then becoming indeterminate. (60)

By assuming any probable value of ϱ, from (48) may be found (61)
corresponding values of ϱ' or ϱ'', from which may be computed (62)
the quantities necessary in the equations of III. or IV. for obtaining values of $\frac{[r'r'']}{[rr']}$ and $\frac{[rr'']}{[rr']}$, which, when ϱ has been correctly assumed, will satisfy (50) or (52), &c.

It is here to be observed, that, in determining the five elements of a parabolic orbit, there are given six conditions, dependent on (63)
α, α', α'', θ, θ', and θ'', to determine five unknown quantities; and therefore either of the quantities α, α', &c., may be rejected. Where the direction of the error in α, α', &c., is unknown, that (64)
should be rejected in which it has the greatest influence, which is θ, θ', or θ'', in (50), (52), and (54); and this is a reason for

not employing these equations in parabolic orbits for the final value of ϱ, where accuracy is desirable; though they are sufficient for de-
(65) termining $\frac{[r'r'']}{[rr']}$ and $\frac{[rr'']}{[rr']}$, which is the object at present in view.

(66) When the heliocentric motion is very small, and τ'' and τ nearly equal, $\varDelta$ may be neglected in (53), which becomes

(67) $$\varrho' = \frac{\sin. \Theta'}{\sin. \theta'} \frac{\tau''^2}{2} R' \left(\frac{1}{R'^3} - \frac{1}{r'^3}\right).$$

Since ϱ' and r' are necessarily positive quantities, r' will be greater or less than R', according as Θ' and θ' have the same or contrary
(68) signs; that is, as the apparent path of the comet is convex or concave towards the sun, a well-known connection between the
(68a) apparent and true orbits. (67) is another expression for the equation for finding ϱ' in the method of Laplace; and under different forms it is used in all the differential methods.

By the conditions (66), without neglecting $\varDelta$, using (8), (53)
(69) becomes $\varrho' = a + \frac{b}{r'^3}$, a and b being known quantities. And taking δ' for the angle between ϱ' and R', and z for that between
(70) ϱ' and r', then $\varrho' = \frac{R' \sin. (\delta' + z)}{\sin. z}$ and $r' = \frac{R' \sin. \delta'}{\sin. z'}$, which give

(71) $$\frac{R' \sin. (\delta' + z)}{\sin. z} = a + b \frac{\sin.^3 z}{R'^3 \sin.^3 \delta'};$$

from which the unknown quantity z is found by trial, and thence ϱ', ϱ, ϱ'', &c.

The quantities P and Q, employed by Gauss, B. [5999] (38), (39), (235), and (256), may also be used with (52), giving

(72) $$Q = \left(\frac{P+1}{P R'' \sin. \Theta'' + R \sin. \Theta} (R' \sin. \Theta' - \varrho' \sin. \theta') - 1\right) 2 r'^3.$$

In which the values of P and Q are approximately $Q = \tau \tau''$ and $P = \frac{\tau''}{\tau}$.

(73) The equations (67) and (71) are approximations only when the heliocentric motion is very small; in other cases it will be necessary to proceed as indicated in (61).

In order to correct the assumed values of $\frac{[r'r'']}{[rr']}$, $\frac{[rr'']}{[rr']}$, in the par-

abola, it will be necessary to compute, either the three distances
from the sun r, r', and r'', or two of these distances, with the (74)
included chord or angle. In the former case, use may be made
of (77) and (80), or of Table III.; in the latter, (82), (83), &c., (75)
are to be employed. In either case, use may or may not be made
of (50), (52), or (54), as circumstances require.

III. If, in Lambert's equation (*vide* Explanation to Table II.
of Bowditch's Appendix to *Mécanique Céleste*) for finding the time
τ'' required in a parabola to describe the angle between r and r',
when these are given together with the chord c'', a quantity q'' be
substituted, such that $\sqrt{(2-q'')\,q''} = \frac{c''}{r+r'}$, then $\tau'' = \frac{(r+r')^{\frac{3}{2}}}{3\sqrt{2}}(3-q'')\sqrt{q''}$ (76)
and $\tau = \frac{(r'+r'')^{\frac{3}{2}}}{3\sqrt{2}}(3-q)\sqrt{q}$. If from these equations q'' and q be
found by means of Table IV., then, by using B. [5996] (40),
$\frac{[r'r'']}{[rr']} = \frac{\tau}{\tau''}\,\frac{(3-q'')\,(1-q)}{(3-q)\,(1-q'')}$ and $\frac{[rr'']}{[rr']} = \frac{\tau'}{\tau''}\,\frac{(3-q'')\,(1-q')}{(3-q')\,(1-q'')}$. Hence it is evident (77)
that in the parabola these quantities depend only on the sums
of the radii and the elapsed times. Table III. contains the log- (78)
arithms of the quantities $\frac{3(1-q)}{(3-q)}$ with the argument $\frac{\tau}{\left(\frac{r'+r''}{2}\right)^{\frac{3}{2}}}$ (Mem. (79)
of Berlin Academy, 1778, p. 148).

When equations (50), (52), and (54) cannot be employed to test the assumed values of ϱ, the above values of q, r, &c., may be employed in the following equation, which should be satisfied. D representing the perihelion distance,

$$4\,D = (2-q'')\,(r+r') - \frac{(r-r')^2}{q''\,(r+r')} = (2-q)\,(r'+r'') - \frac{(r'-r'')^2}{q'\,(r'+r'')}. \qquad (80)$$

This has no other recommendation than that by its use the computation of the chord c is avoided.

Perhaps the following mode of testing the assumed values of
ϱ, in which the use of (50), (59), and (80) is avoided, is to be (81)
preferred. It is essentially the same as Olber's method, with the
corrections of $\frac{[r'r'']}{[rr']}$ and of $\frac{[rr'']}{[rr']}$ taken into account.

$$r^2 = R^2 + \varrho^2 - 2\,R\,\varrho\cos.\,\delta_1. \qquad r''^2 = R''^2 + M^2\varrho^2 - 2\,M\,\varrho\,R''\cos.\,\delta_2. \qquad (82)$$

(83) $\cos.\,(v''-v)=\frac{1}{r\,r''}\,[R\,R''\cos.\,\delta_3-(R''\cos.\,\delta_4+R\,M\cos.\,\delta_5)\,\varrho+M\,\varrho^2\cos.\,\delta_6]$.

(84) In which $M=\frac{\rho''}{\rho}$, $v''-v$ the angle between r and r'', and δ_1, δ_2, &c. the angles comprised between $R\,\varrho$, $R''\,\varrho''=R''\,M\,\varrho$, &c., which are computed as follows:—

(85) $$\cos.\,\delta_1=\sin.\,\Theta\,\sin.\,\theta+\cos.\,\Theta\,\cos.\,\theta\,\cos.\,(\odot-\alpha),\ \&c.$$

When (31) is used, $\theta=\theta''=0$, and then

$$\cos.\,\delta_1=\cos.\,\Theta\,\cos.\,(\odot-\alpha),\ \&c.$$

(86) The value of $(1-q')$ (76) may be thus expressed: $1-q'=\frac{2\sqrt{r\,r''}\cos.\,\frac{1}{2}(v''-v)}{r+r''}$, which, substituted in $\tau'=\frac{(r+r'')^{\frac{3}{2}}}{3\sqrt{2}}\,(3-q')\sqrt{q'}$, should give the true value of τ'. Ordinarily q' is not ascertained with much accuracy in this way, it being uncertain in the same degree as the value of the chord computed as in the method of Olbers: in the present instance, the angle $(v''-v)$ is adopted instead of the chord, with a view to the correction of the assumed values of $\frac{[r'\,r'']}{[r\,r']}$ and $\frac{[r\,r'']}{[r\,r']}$. The angles between r, r', and r'' are found by

(87) trial from the relations $\frac{\sin.\,(v''-v')}{\sin.\,(v'-v)}=\frac{r}{r''}\,\frac{[r'\,r'']}{[r\,r']}$ and $(v''-v')+(v'-v)=(v''-v)$; or $(v'-v)$ may be found directly from the equation, $\tan.\,(v'-v)=\frac{\sin.\,(v''-v)}{\frac{r}{r''}\frac{[r'\,r'']}{[r\,r']}+\cos.\,(v''-v)}$. With $(v'-v)$ thus found, r' is com-

(88) puted from $r'=\frac{[r\,r']}{[r\,r'']}\,\frac{\sin.\,(v''-v)}{\sin.\,(v'-v)}\,r''$. With these values of r, r', and r'',

(89) $\frac{[r'\,r'']}{[r\,r']}$ and $\frac{[r\,r'']}{[r\,r']}$ may be corrected by (78), or by (86) and (77), or by Table V.

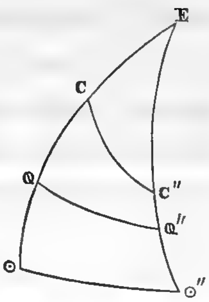
(90) IV. The values of $\frac{\rho''}{\rho}$, &c., determined on the supposition of a parabolic orbit, will be affected by the introduction of an eccen-

(91) tricity by terms of the order $\frac{\tau^4}{a}$, a being the semi-axis of the orbit.

(91 *a*) In order further to correct $\frac{[r'\,r'']}{[r\,r']}$ and $\frac{[r\,r'']}{[r\,r']}$, two heliocentric distances must be found, with their included angle or chord, by suppos-

(92) ing (90) to be correct. Thence, by (87) and (88), the third heliocentric distance and the remaining angles.

(93) When (59) is employed, either of the above angles may be found by the solution of the spherical triangle $C\,E\,C''$, &c., in



which α and α'' are the geocentric, and C and C'' the heliocentric places of the comet, and $\odot$, $\odot''$, those of the sun; the angle at E, and $E\,\alpha$, $E\,\alpha''$, are known, and if from (94) are found $z = C\,\alpha$ and $z'' = C\,\alpha''$, then there are given the two sides $E\,C$ and $E\,C''$ and the angle at E, to find the side $C\,C'' = v'' - v$. z and z'' are found from ϱ and ϱ'' by trial from the equation $\frac{\sin.\,(\delta + z)}{\sin.\,z} = \frac{\rho}{R}$, &c., $\sin.\,z = \frac{R\,\sin.\,\delta}{r}$, &c. (94)

Otherwise, when right ascensions and declinations are employed, the included chord may be used.

$c^2 = (x'' - x)^2 + (y'' - y)^2 + (z'' - z)^2$, this form being susceptible (95) of more accurate computation from the tables, though it is less convenient than the simpler expression which may be derived from it, B. [5994] (106), &c.; x, y, and z here represent the heliocentric (96) coördinates of the comet. The assumed value of q' (76)

$$q'\,(2 - q') = \frac{c^2}{(r + r'')^2} = \sin.^2 n,\ (1 - q') = \cos.\,n,\ q' = \tfrac{1}{2}\left(\frac{\sin.\,n}{\cos.\,\frac{1}{2}n}\right)^2 = 2\,\sin.^2\tfrac{1}{2}n, \qquad (97)$$

substituted in Gauss's equations B. [5995], (28), (39), [5997] (101), &c., gives, by combining in one equation the expressions for τ' in all the conic sections,

$$\tau' = \frac{(r + r'')^{\frac{3}{2}}\,(1 - q')^{\frac{3}{2}}}{\sqrt{2}}\left(\frac{q'}{1 - q'}\ {}^{+\,2\,\sin.^2\frac{1}{2}g'}_{-\,2\,\sin.^2\frac{1}{2}h'\,\sec.\,h'}\right)^{\frac{1}{2}}\left[1 + \tfrac{2}{3}\left(\frac{q'}{1 - q'}\ {}^{+\,2\,\sin.^2\frac{1}{2}g'}_{-\,2\,\sin.^2\frac{1}{2}h'\,\sec.\,h'}\right)\frac{G'}{H'}\right], \qquad (98)$$

in which $G' = [1 + \frac{3}{10}\sin.^2 g' + \frac{9}{56}\sin.^4 g' + \&c.]$, and $H' = [1 - \frac{3}{10}\tan.^2 h' +$ (99) $\frac{9}{56}\tan.^4 h' - \&c.]$. The values of G' and H' being given in Tables I. and II. (98) contains but one unknown quantity, g' when the values of r, r'', and q' are elliptical, h' when they are hyper- (100) bolic, and $g' = h' = 0$ when they are parabolic. The quantity within the brackets in (98) is the coefficient of $[r\,r'']$ in the equation $\tau'\sqrt{p} = [r\,r'']\ \mathbf{y}'$, where p is the semiparameter and (101)

$$\mathbf{y}' = \left[1 + \tfrac{2}{3}\left(\frac{q'}{1 - q'}\ {}^{+\,2\,\sin.^2\frac{1}{2}g'}_{-\,2\,\sin.^2\frac{1}{2}h'\,\sec.\,h'}\right)\frac{G'}{H'}\right], \qquad (102)$$

which can be found from (98) only by approximation.

(103) When the angle $(v''-v)$ is used (93) instead of the chord, q' may be thus found, B. [5995] (30), (31), and (86):

(104) $$(r+r'')\,(1-q')=2\sqrt{rr''}\cos. f';$$

(105) in which $f'=\frac{1}{2}\,(v''-v)$, $q'=\frac{1}{(r+r'')}\left[\left(\frac{\sin. f'}{\cos. \frac{1}{2}f'}\right)^2\sqrt{rr''}+(\sqrt{r}-\sqrt{r''})^2\right]$.
When $\mathbf{y}'$ and g' have been found from (98), g and g'' are derived from g' by the equations,

(106) $$\sin. g=\sqrt{\frac{r'}{r}}\,\frac{\sin. f}{\sin. f'}\,.\,\sin. g' \text{ and } \sin. g''=\sqrt{\frac{r'}{r''}}\,\frac{\sin. f''}{\sin. f'}\sin. g';$$

or in the case of (98) being satisfied by the hyperbolic values,

(107) $$\tan. h=\sqrt{\frac{r'}{r}}\,\frac{\sin. f}{\sin. f'}\tan. h' \text{ and } \tan. h''\sqrt{\frac{r'}{r}} \text{ and } \sqrt{\frac{r'}{r''}}\,\frac{\sin. f''}{\sin. f'}\tan. h',$$

B. [5995] (70), [5997] (6), &c., which, used in (102), by changing the accents, will give $\mathbf{y}$ and $\mathbf{y}''$ and thence $\frac{[r'r'']}{[rr']}=\frac{\tau}{\tau''}\,\frac{\mathbf{y}''}{\mathbf{y}}$, and $\frac{[rr'']}{[rr']}\,\frac{\tau'}{\tau''}\,\frac{\mathbf{y}''}{\mathbf{y}'}$, which are to be used in (50), (52), or (54). When these equations cannot be employed (60), two independent values, q and q'', are to be found from the assumed value of ρ (91a); when this is correct, (98) will give the observed values of τ and τ'', or τ'.

V. The following example will serve as an illustration of the preceding propositions. The positions employed are those of Halley's comet in October, 1836, computed from an ephemeris, and corrected for aberration, but affected by parallax (46), (47), as seen from a point on the earth's surface in North lat. 42° 23′, and lon. W. $4^{h.}\ 44^{m.}$

Gr. M. S. T.	Sun's Tabular AR.	Sun's Parallax in AR.	Sun's Tabular Dec.	Sun's Parallax in Dec.	Tabular Value of R.	Cor. of R for Parallax.	Comet's AR.	Comet's Dec.
1836, Oct. 4.50000	190° 03′ 11″.5	−5″.9	−4° 22′ 04″.4	−5″.6	0.9994521	+135	α 107° 27′ 33″.0	δ +45° 32′ 15″.9
" 14.50000	199 19 24.2	−5.9	−8 10 21.7	−5.4	0.9966131	+155	α' 233 57 21.1	δ' +38 20 33.8
" 23.50000	207 47 11.4	−6.0	−11 26 17.9	−5.2	0.9941330	+172	α'' 256 09 20.7	δ'' − 0 06 59.8

To find the angles δ, δ', and δ'', we have

$$\cos. \delta=\sin. \Theta \sin. \theta+\cos. \Theta \cos. \theta \cos. (\odot-\alpha).$$

To find C' (57)

$$\cot. w=\cot. (\alpha''-\alpha)\left(\frac{\tan. \delta''}{\tan. \delta}\sec. (\alpha''-\alpha)-1\right),\quad C'=\alpha+w.$$

For computing the known terms in (57) they may be a little

simplified by putting $m = \sin. (C' - \alpha) \cot. \theta$, by which they become of the form $\sin. (C' - \alpha') - m \tan. \theta'$, $\sin. (C' - \odot) - m \tan. \Theta$, &c.

To find $\frac{\rho''}{\rho}$, (28) may be employed, using right ascensions and declinations; and for $\frac{\rho'}{\rho}$, (4) may be used, with declinations alone, since $\sin. \theta''$, the coefficient of ρ'', happens to be very small, and $\sin. \theta$, $\sin. \Theta$, &c., are elsewhere used.

For convenience in reference, the known coefficients in (57) may be denoted, in the order in which they are then placed, by a_0, b_0, c_0, d_0; those in (28), by a_1, b_1, c_1, &c.

$\log. a_0$	8.4337430	$\sin. \theta$	9.8535231	$\log. \tau''$	9.2355814
$\log. b_0$	$\overset{n}{0}.0830200$	$\sin. \theta'$	9.7926466	$\log. \tau$	9.1898239
$\log. c_0$	0.0600656	$\sin. \theta''$	$\overset{n}{7}.3086315$	$\log. \tau'$	9.5143350
d_0	-1.0623875	$\sin. \Theta$	$\overset{n}{8}.8818844$	r^2	$= 0.9989317 - 0.0693162\,\rho + \rho^2$
$\log. a_1$	9.7505754	$\sin. \Theta'$	$\overset{n}{9}.1528482$	r'^2	$= 0.9932688 - 1.0974287\,\rho' + \rho'^2$
$\log. b_1$	$\overset{n}{9}.5773059$	$\sin. \Theta''$	$\overset{n}{9}.2974047$	r''^2	$= 0.9883345 - 1.2953963\,\rho'' + \rho''^2$
$\log. c_1$	$\overset{n}{9}.8388654$	$\cos. \delta$	8.5400370	$\log. \frac{\tau}{\tau''}$	9.9542425
$\log. d_1$	9.7487023	$\cos. \delta'$	9.7408130	$\log. \frac{\tau'}{\tau''}$	0.2787536
e_1	-0.4297613	$\cos. \delta''$	9.8139207		

From the direction of the comet's motion, it follows from (30) that neither (28) nor (4) is the most favorable for determining $\frac{\rho''}{\rho}$ and $\frac{\rho'}{\rho}$; the terms neglected in (28) in the first approximation have also somewhat larger coefficients than in (44) or (4). The latter give for approximations, $\log. \frac{\rho''}{\rho} = 0.112$ and $\log. \frac{\rho'}{\rho} = 9.742$.

As the geocentric motion of the comet is very large, it is probable that its distance from the earth is small, and we may assume $\rho = \frac{1}{3}$, which gives,

First Approximation.

$\log. \rho$	9.523	r	1.0425	$\log. \dfrac{\tau''}{\left(\frac{r+r'}{2}\right)^{\frac{3}{2}}}$	9.2518	$\log. \frac{1}{\mathbf{y}''}$	9.99767
$\log. \rho'$	9.265	r'	0.9085	$\log. \dfrac{\tau}{\left(\frac{r'+r''}{2}\right)^{\frac{3}{2}}}$	9.2983	$\log. \frac{1}{\mathbf{y}}$	9.99710
$\log. \rho''$	9.635	r''	0.7843	$\log. \dfrac{\tau'}{\left(\frac{r+r''}{2}\right)^{\frac{3}{2}}}$	9.5733	$\log. \frac{1}{\mathbf{y}'}$	9.98935

The last values being taken from Table III.

$$\log. \frac{[r' r'']}{[r r']} = \log. \frac{\tau}{\tau''} \frac{\mathbf{y}''}{\mathbf{y}} = 9.95367 \qquad \log. \frac{[r r'']}{[r r']} = 0.27043$$

With these is obtained from (57) a computed value of log. $\varrho' =$ 9.319, instead of the assumed value log. $\varrho' = 9.265$, indicating that the assumed value log. $\varrho = 9.523$ was too small by about 0.050. Taking, therefore, for a corrected value, log. $\varrho = 9.573$, and using the new values of $\frac{[r' r'']}{[r r']}$ and $\frac{[r r'']}{[r r']}$ in (4) and (28), they give log. $\frac{\varrho''}{\varrho} = 0.11546$ and log. $\frac{\varrho'}{\varrho} = 9.74500$.

Second Approximation.

log. ϱ	9.573	r	1.0548	$\frac{\tau''}{\left(\frac{r+r'}{2}\right)^{\frac{3}{2}}}$	9.2507	$\frac{1}{\mathbf{y}''}$	9.99768
log. ϱ'	9.317	r'	0.8993	$\frac{\tau}{\left(\frac{r'+r''}{2}\right)^{\frac{3}{2}}}$	9.3070	$\frac{1}{\mathbf{y}}$	9.99698
log. ϱ''	9.688	r''	0.7712	$\frac{\tau'}{\left(\frac{r+r''}{2}\right)^{\frac{3}{2}}}$	9.5736	$\frac{1}{\mathbf{y}'}$	9.98934

From the latter are derived log. $\frac{[r' r'']}{[r r']} = 9.95354$ log. $\frac{[r r'']}{[r r']} = 0.27041$, which give a new computed value, log. $\varrho' = 9.3093$, assumed log. $\varrho' = 9.3170$; and the corrected values log. $\frac{\varrho''}{\varrho} = 0.11541$, and log. $\frac{\varrho'}{\varrho} = 9.74494$, differing in the last decimal place from the previous values.

In these two assumptions the elements have been assumed as parabolic; further correction may be made by using the more general method (IV.).

Third Approximation.

log. ϱ	9.56436	r	1.05262	$v' - v$	$11^\circ\ 11'\ 53''$	log. sin.² g''	6.59134
log. ϱ'	9.30930	r'	0.90063	$v'' - v'$	13 44 49	log. sin.² g	6.63464
log. ϱ''	9.67977	r''	0.77297	$v'' - v$	24 56 42	log. sin.² g'	7.21514

log. $\mathbf{y}$	0.0030007	log. $\frac{[r' r'']}{[r r']}$	9.9535654	Computed log. ϱ'	9.30893
log. $\mathbf{y}'$	0.0106495	log. $\frac{[r r'']}{[r r']}$	0.2704277	Assumed "	9.30930
log. $\mathbf{y}''$	0.0023236				

Whence the third approximation, taking into account the eccentricity of the orbit, gives log. $\frac{\varrho''}{\varrho} = 0.1154807$ log. $\frac{\varrho'}{\varrho}$ 9.7449467 ;

with either of which the observed places may be satisfied to within one or two seconds of arc.

The final values are log. $\frac{\rho''}{\rho} = 0.1154850$ and log. $\frac{\rho'}{\rho} = 9.7449468$.

The limit of error allowable in these ratios will be nearly that (107*a*)
of the errors of $\frac{\tau}{\tau''}$ and $\frac{\tau'}{\tau''}$, which can be derived from the time required by the comet's apparent motion to pass over the probable error of α, θ, &c. With the best observations, t, t', and t'' will be liable to errors which will frequently affect the values log. $\frac{\rho''}{\rho}$ and log. $\frac{\rho'}{\rho}$ in the fifth place of decimals, a consideration which may serve to restrict a useless refinement.

Explanation of the Tables.

VI. Table I. contains the logarithmic values of the expression $\frac{3}{4}\,\frac{2g - \sin. 2g}{\sin.^3 g} = G = 1 + \frac{3}{10}\sin.^2 g +$, &c., with the argument log. $\sin.^2 g$; and is used in finding $\mathbf{y}$, as shown in (102), &c.

It might also be used for finding the time required in an ellipse to describe the angle between r and r', when these are given with the included chord c, and the semiaxis a. For, if $\sin.^2 \frac{1}{2}\chi = \frac{r + r' - c}{4a}$ and $\sin.^2 \frac{1}{2}\varepsilon = \frac{r + r' + c}{4a}$, then $\tau = a^{\frac{3}{2}}(\varepsilon - \sin.\ \varepsilon - (\chi - \sin.\ \chi))$. Gauss, *Theor. Mot.*, p. 120. Which may be solved by means of Table I.

It may also be used in computing an ephemeris in the following way.

Let x_0, x''_0, &c., $[r_0\, r''_0]$, $\frac{\tau'_0}{\mathbf{y}_0}$, and $v''_0 - v_0$, be the values of the heliocentric coördinates x, x'', &c. of a comet at any two epochs separated by the interval of time τ'_0; the first and last days of the interval for which the ephemeris is to be computed may be conveniently adopted. For any intermediate time we find from known relations,

$$\tan.\alpha' = \frac{Y' + M_2\frac{\tau}{\mathbf{y}} + N_2\frac{\tau''}{\mathbf{y}''}}{X' + M_1\frac{\tau}{\mathbf{y}} + N_1\frac{\tau''}{\mathbf{y}''}},\ \tan.\theta' = \frac{Z' + M_3\frac{\tau}{\mathbf{y}} + N_3\frac{\tau''}{\mathbf{y}''}}{X' + M_1\frac{\tau}{\mathbf{y}} + N_1\frac{\tau''}{\mathbf{y}''}}\cos.\alpha',\ \rho' = \frac{Z' + M_3\frac{\tau}{\mathbf{y}} + N_3\frac{\tau''}{\mathbf{y}''}}{\sin.\ \theta'}.$$

In which X', Y', and Z' are the sun's geocentric coördinates; $M_1 = \frac{\mathbf{y}'_0}{\tau'_0} x_0$, $M_2 = \frac{\mathbf{y}'_0}{\tau'_0} y_0$, $M_3 = \frac{\mathbf{y}'_0}{\tau'_0} z_0$, $N_1 = \frac{\mathbf{y}'_0}{\tau'_0} x''_0$, $N_2 = \frac{\mathbf{y}'_0}{\tau'_0} y''_0$, and $N_3 = \frac{\mathbf{y}'_0}{\tau'_0} z''_0$, are known constant quantities; τ and τ'' are the known variables, having the same signification as in (6); and $\frac{1}{\mathbf{y}''}$ and $\frac{1}{\mathbf{y}}$, the unknown quantities to be found from (108),

(108) $$\frac{1}{\mathbf{y}''} = 1 - \frac{\sqrt{2}}{3} \frac{\sqrt{\tau''}}{p^{\frac{3}{4}}} \left(\frac{\tan. f''}{\mathbf{y}''}\right)^{\frac{3}{2}} \frac{G''}{H''}.$$

$\frac{1}{\mathbf{y}''}$ can therefore be found accurate to terms of the second order,
(109) when the error of $\tan. f''$ is of the first order. When $v''_0 - v_0$ is small, the error of the first approximation to $\tan. f''$, as found by (87), will be of the second order, and consequently that of $\frac{1}{\mathbf{y}''}$ of the third.

Assuming for a first approximation $\frac{\mathbf{y}''}{\mathbf{y}} = 1$, or $\frac{[r' r''_0]}{[r_0 r']} = \frac{\tau}{\tau''} \frac{\mathbf{y}''}{\mathbf{y}} = \frac{\tau}{\tau''}$, we may find $(v'' - v')$ and $(v' - v)$, as in (87), by trial from the equations $\frac{\sin. (v'' - v')}{\sin. (v' - v)} = \frac{r_0}{r''_0} \frac{[r' r''_0]}{[r_0 r']} = L$, and $(v''_0 - v_0) = (v' - v) + (v'' - v')$;
(110) or from the expression, $\tan. (v' - v) = \frac{\sin. (v''_0 - v_0)}{L + \cos. (v''_0 - v_0)}$.

Substituting the value thus obtained of $\tan. \frac{1}{2} (v' - v) = \tan. f''$ in (108), there results a corrected value of $\frac{1}{\mathbf{y}''}$. If the elements are elliptical, G'' is used, and its logarithm is taken from Table I. with
(111) the argument $\sin.^2 g'' = \frac{\tau''}{\mathbf{y}''} \frac{\tan. f''}{2a\sqrt{p}}$.

In the hyperbola H'' is employed, and its logarithm is found from Tables I. and II., with the argument $\tan.^2 h'' = -\frac{\tau''}{\mathbf{y}''} \frac{\tan. f''}{2a\sqrt{p}}$.

If they are parabolic $G'' = H'' = 1$.

Having from (108) found corrected values of $\frac{1}{\mathbf{y}''}$ and $\frac{1}{\mathbf{y}}$, they are to be used for new values of $\tan. f''$ and $\tan. f$. The smaller the latter quantities are, the more rapid (109) will be the convergence to the true values of $\frac{1}{\mathbf{y}''}$ and $\frac{1}{\mathbf{y}}$; these may commonly be found with accuracy to seven places of decimals with five-figure logarithms. The amount of allowable error in $\frac{1}{\mathbf{y}''}$ and $\frac{1}{\mathbf{y}}$ may be estimated from considerations similar to those pointed out in (107 a).

Table II. contains values of the logarithms of $HG = 1 + \frac{81}{350}$

$\tan.^4 h'' +$, &c. This table therefore gives the logarithm of the coefficient, reducing $\frac{1}{G}$ to $H = 1 - \frac{3}{10}\tan.^2 h + \&c.$, H being the development of the expression $\frac{3}{4}\frac{2h - \sin. 2h}{\sin.^3 h}$ when $\sin.^2 h$ is negative; and is taken from Table II. with the argument log. $\tan.^2 h$.

Table III. contains the logarithms of $\frac{1}{\mathbf{y}}$ in the parabola, with the argument $\log. \frac{\tau''}{\left(\frac{r+r'}{2}\right)^{\frac{3}{2}}} = \log. a$. (*Vide* Mem. of Berlin Acad. for 1778, pp. 148, 150.)

Table IV. contains the logarithms of $\frac{3 - q''}{3\sqrt{2}}$ in the parabola, with the argument $\log. \frac{\tau''}{(r+r')^{\frac{3}{2}}}$. It is used in connection with (76).

Table V. contains the logarithms of $\mathbf{y}''$ in the parabola, with the argument $\log. (1 - q'')$ and may be used with (89).

Table VI. contains the corrections to be applied to the sun's longitudes, as taken from the Nautical Almanac, to refer them to the mean equinox of Jan. 1st of each year; and may be used in preparing the sun's places for computing the elements of a comet.

TABLE I.

$\sin.^2 g$	log. G.	Dif.	$\sin.^2 g$	log. G.	Dif.	$\sin.^2 g$	log. G.	Dif.	$\sin.^2 g$	log. G.	Dif.	$\sin.^2 g$	log. G.	Dif.	$\sin.^2 g$	log. G.	Dif.
	0.000			0.000			0.000			0.000			0 00			0.00	
4.00	0001		6 50	0412		7.13	1758		7.76	7514		8.039	14313		8.102	16558	
.40	0003	2	.51	0422	10	.14	1799	41	.77	7689	175	.040	14346	33	.103	16596	38
4.80	0008	5	.52	0432	10	.15	1841	42	.78	7869	180	.041	14379	33	.104	16634	38
5 00	0013	5	.53	0442	10	.16	1884	43	.79	8053	184	.042	14412	33	.105	16673	39
.10	0016	3	.54	0452	10	.17	1928	44	.80	8241	188	.043	14445	33	.106	16712	39
.20	0020	4	.55	0462	10	.18	1973	45	.81	8433	192	.044	14478	33	.107	16751	39
.30	0026	6	.56	0473	11	.19	2019	46	.82	8630	197	.045	14511	33	.108	16790	39
.40	0032	6	.57	0484	11	.20	2066	47	.83	8832	202	.046	14545	34	.109	16829	39
.50	0041	9	.58	0496	12	21	2114	48	.84	9038	206	.047	14679	34	.110	16868	39
.60	0052	11	.59	0507	11	.22	2163	49	.85	9249	211	.048	14713	34	.111	16907	39
.70	0065	13	.60	0519	12	.23	2213	50	.86	9465	216	.049	14747	34	.112	16946	39
.80	0082	17	.61	0531	12	.24	2265	52	.87	9686	221	.050	14681	34	.113	16985	39
5.90	0104	22	.62	0543	12	.25	2318	53	.88	9912	226	.051	14715	34	.114	17024	39
6.00	0130	26	.63	0556	13	.26	2372	54	.89	10143	231	.052	14749	34	.115	17064	40
.01	0133	3	.64	0568	12	.27	2427	55	.90	10380	237	.053	14783	34	.116	17104	40
.02	0136	3	.65	0581	13	.28	2484	57	.91	10623	243	.054	14817	34	.117	17144	40
.03	0139	3	.66	0595	14	.29	2542	58	.92	10871	248	.055	14851	34	.118	17184	40
.04	0142	3	.67	0609	14	.30	2601	59	.93	11125	254	.056	14885	34	.119	17224	40
.05	0146	4	.68	0624	15	.31	2662	61	.94	11385	260	.057	14920	35	.120	17264	40
.06	0149	3	.69	0638	14	.32	2724	62	.95	11651	266	.058	14955	35	.121	17304	40
.07	0153	4	.70	0653	15	.33	2788	64	.96	11923	272	.059	14990	35	.122	17344	40
.08	0156	3	.71	0668	15	.34	2853	65	.97	12202	279	.060	15025	35	.123	17384	40
.09	0160	4	.72	0684	16	.35	2919	66	.98	12488	286	.061	15060	35	.124	17424	40
.10	0164	4	.73	0700	16	.36	2987	68	7.99	12780	292	.062	15095	35	.125	17464	40
.11	0168	4	.74	0716	16	.37	3057	70	8.000	13079	299	.063	15130	35	.126	17505	41
.12	0172	4	.75	0733	17	.38	3128	71	.001	13109	30	.064	15165	35	.127	17546	41
.13	0176	4	.76	0750	17	.39	3201	73	.002	13139	30	.065	15200	35	.128	17587	41
.14	0180	4	.77	0768	18	.40	3276	75	.003	13169	30	.066	15235	35	.129	17628	41
.15	0184	4	.78	0786	18	.41	3353	77	.004	13199	30	.067	15270	35	.130	17669	41
.16	0188	4	.79	0804	18	.42	3431	78	.005	13230	31	.068	15305	35	.131	17710	41
.17	0193	5	.80	0822	18	.43	3511	80	.006	13261	31	.069	15341	36	.132	17751	41
.18	0197	4	.81	0841	19	.44	3593	82	.007	13292	31	.070	15377	36	.133	17792	41
.19	0202	5	.82	0860	19	.45	3676	83	.008	13323	31	.071	15413	36	.134	17833	41
.20	0206	4	.83	0880	20	.46	3761	85	.009	13354	31	.072	15449	36	.135	17874	41
.21	0211	5	.84	0901	21	.47	3849	88	.010	13385	31	.073	15485	36	.136	17915	41
.22	0216	5	.85	0922	21	.48	3939	90	.011	13416	31	.074	15521	36	.137	17956	41
.23	0221	5	.86	0944	22	.49	4031	92	.012	13447	31	.075	15557	36	.138	17998	42
.24	0226	5	.87	0966	22	.50	4125	94	.013	13478	31	.076	15593	36	.139	18040	42
.25	0231	5	.88	0988	22	.51	4221	96	.014	13509	31	.077	15629	36	.140	18082	42
.26	0237	6	.89	1011	23	.52	4319	98	.015	13540	31	.078	15665	36	.141	18124	42
.27	0242	5	.90	1035	24	.53	4420	101	.016	13571	31	.079	15701	36	.142	18166	42
.28	0248	6	.91	1059	24	.54	4523	103	.017	13602	31	.080	15738	37	.143	18208	42
.29	0254	6	.92	1083	24	.55	4628	105	.018	13634	32	.081	15774	36	.144	18250	42
.30	0260	6	.93	1108	25	.56	4737	109	.019	13666	32	.082	15811	37	.145	18292	42
.31	0266	6	.94	1134	26	.57	4848	111	.020	13698	32	.083	15847	36	.146	18334	42
.32	0272	6	.95	1160	26	.58	4961	113	.021	13730	32	.084	15884	37	.147	18376	42
.33	0278	6	.96	1188	28	.59	5077	116	.022	13762	32	.085	15921	37	.148	18419	43
.34	0285	7	.97	1215	27	.60	5195	118	.023	13794	32	.086	15958	37	.149	18462	43
.35	0292	7	.98	1244	29	.61	5316	121	.024	13826	32	.087	15995	37	.150	18505	43
.36	0299	7	6 99	1273	29	.62	5440	124	.025	13858	32	.088	16032	37	.151	18548	43
.37	0306	7	7.00	1303	30	.63	5567	127	.026	13890	32	.089	16069	37	.152	18591	43
.38	0313	7	.01	1334	31	.64	5697	130	.027	13922	32	.090	16106	37	.153	18634	43
.39	0320	7	.02	1365	31	.65	5830	133	.028	13954	32	.091	16143	37	.154	18677	43
.40	0327	7	.03	1397	32	.66	5966	136	.029	13986	32	.092	16180	37	.155	18720	43
.41	0335	8	.04	1429	32	.67	6105	139	.030	14018	32	.093	16217	37	.156	18763	43
.42	0343	8	.05	1462	33	.68	6248	143	.031	14050	32	.094	16254	37	.157	18806	43
.43	0351	8	.06	1496	34	.69	6394	146	.032	14082	32	.095	16292	38	.158	18850	44
.44	0359	8	.07	1531	35	.70	6543	149	.033	14115	33	.096	16330	38	.159	18894	44
.45	0367	8	.08	1567	36	.71	6695	152	.034	14148	33	.097	16368	38	.160	18938	44
.46	0376	9	.09	1604	37	.72	6851	156	.035	14181	33	.098	16406	38	.161	18982	44
.47	0385	9	.10	1641	37	.73	7011	160	.036	14214	33	.099	16444	38	.162	19026	44
.48	0394	9	.11	1679	38	.74	7175	164	.037	14247	33	.100	16482	38	.163	19070	44
.49	0403	9	.12	1718	39	.75	7343	168	.038	14280	33	.101	16520	38	.164	19114	44
6 50	0412	9	7.13	1758	40	7 .76	7514	171	8.039	14313	33	8.102	16558	38	8.165	19158	44

TABLE I.—(CONTINUED.)

sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.
	0.00			0.00			0.00			0.00			0.00			0.00	
8.165	19158		8.230	22272		8.295	25896		8.360	30114		8.425	35027		8.490	40751	
.166	19202	44	.231	22324	52	.296	25956	60	.361	30184	70	.426	35109	82	.491	40846	95
.167	19247	45	.232	22376	52	.297	26016	60	.362	30254	70	.427	35191	82	.492	40941	95
.168	19292	45	.233	22428	52	.298	26076	60	.363	30324	70	.428	35273	82	.493	41037	96
.169	19337	45	.234	22480	52	.299	26137	61	.364	30395	71	.429	35355	82	.494	41133	96
.170	19382	45	.235	22532	52	.300	26198	61	.365	30466	71	.430	35437	82	.495	41229	96
.171	19427	45	.236	22584	52	.301	26259	61	.366	30537	71	.431	35519	82	.496	41325	96
.172	19472	45	.237	22636	52	.302	26320	61	.367	30608	71	.432	35602	83	.497	41422	97
.173	19517	45	.238	22689	53	.303	26381	61	.368	30679	71	.433	35685	83	.498	41519	97
.174	19562	45	.239	22742	53	.304	26442	61	.369	30750	71	.434	35768	83	.499	41616	97
.175	19607	45	.240	22795	53	.305	26503	61	.370	30822	72	.435	35851	83	.500	41713	97
.176	19652	45	.241	22848	53	.306	26565	62	.371	30894	72	.436	35935	84	.501	41810	97
.177	19698	46	.242	22901	53	.307	26627	62	.372	30966	72	.437	36019	84	.502	41908	98
.178	19744	46	.243	22954	53	.308	26689	62	.373	31038	72	.438	36103	84	.503	42006	98
.179	19790	46	.244	23007	53	.309	26751	62	.374	31110	72	.439	36187	84	.504	42104	98
.180	19836	46	.245	23060	53	.310	26813	62	.375	31182	72	.440	36271	84	.505	42202	98
.181	19882	46	.246	23114	54	.311	26875	62	.376	31255	73	.441	36356	85	.506	42301	99
.182	19928	46	.247	23168	54	.312	26937	62	.377	31328	73	.442	36441	85	.507	42400	99
.183	19974	46	.248	23222	54	.313	27000	63	.378	31401	73	.443	36526	85	.508	42499	99
.184	20020	46	.249	23276	54	.314	27063	63	.379	31474	73	.444	36611	85	.509	42598	99
.185	20066	46	.250	23330	54	.315	27126	63	.380	31547	73	.445	36696	85	.510	42697	99
.186	20113	47	.251	23384	54	.316	27189	63	.381	31620	73	.446	36782	86	.511	42797	100
.187	20160	47	.252	23438	54	.317	27252	63	.382	31694	74	.447	36868	86	.512	42897	100
.188	20207	47	.253	23493	55	.318	27315	63	.383	31768	74	.448	36954	86	.513	42997	100
.189	20254	47	.254	23548	55	.319	27379	64	.384	31842	74	.449	37040	86	.514	43097	100
.190	20301	47	.255	23603	55	.320	27443	64	.385	31916	74	.450	37126	86	.515	43198	101
.191	20348	47	.256	23658	55	.321	27507	64	.386	31990	74	.451	37213	87	.516	43299	101
.192	20395	47	.257	23713	55	.322	27571	64	.387	32064	74	.452	37300	87	.517	43400	101
.193	20442	47	.258	23768	55	.323	27635	64	.388	32139	75	.453	37387	87	.518	43501	101
.194	20489	47	.259	23823	55	.324	27699	64	.389	32214	75	.454	37474	87	.519	43602	101
.195	20537	48	.260	23878	55	.325	27763	64	.390	32289	75	.455	37561	87	.520	43704	102
.196	20585	48	.261	23934	56	.326	27828	65	.391	32364	75	.456	37649	88	.521	43806	102
.197	20633	48	.262	23990	56	.327	27893	65	.392	32439	75	.457	37737	88	.522	43908	102
.198	20681	48	.263	24046	56	.328	27958	65	.393	32515	76	.458	37825	88	.523	44011	103
.199	20729	48	.264	24102	56	.329	28023	65	.394	32591	76	.459	37913	88	.524	44114	103
.200	20777	48	265	24158	56	.330	28088	65	.395	32667	76	.460	38001	88	.525	44217	103
.201	20825	48	.266	24214	56	.331	28153	65	.396	32743	76	.461	38090	89	.526	44320	103
.202	20873	48	.267	24270	56	.332	28218	65	.397	32819	76	.462	38179	89	.527	44424	104
.203	20921	48	.268	24326	56	.333	28284	66	.398	32895	76	.463	38268	89	.528	44528	104
.204	20970	49	.269	24382	56	.334	28370	66	.399	32971	76	.464	38357	89	.529	44632	104
.205	21019	49	.270	24438	56	.335	28416	66	.400	33048	77	.465	38446	89	.530	44736	104
.206	21068	49	.271	24495	57	.336	28482	66	.401	33125	77	.466	38536	90	.531	44840	104
.207	21117	49	.272	24552	57	.337	28548	66	.402	33202	77	.467	38626	90	.532	44945	105
.208	21166	49	.273	24609	57	.338	28614	66	.403	33279	77	.468	38716	90	.533	45050	105
.209	21215	49	.274	24666	57	.339	28681	67	.404	33356	77	.469	38806	90	.534	45155	105
.210	21264	49	.275	24723	57	.340	28748	67	.405	33434	78	.470	38896	90	.535	45260	105
.211	21313	49	.276	24780	57	.341	28815	67	.406	33512	78	.471	38987	91	.536	45366	106
.212	21362	49	.277	24837	57	.342	28882	67	.407	33590	78	.472	39078	91	.537	45472	106
.213	21412	50	.278	24895	58	.343	28949	67	.408	33668	78	.473	39169	91	.538	45578	106
.214	21462	50	.279	24953	58	.344	29016	67	.409	33747	79	.474	39260	91	.539	45685	107
.215	21512	50	.280	25011	58	.345	29083	67	.410	33826	79	.475	39351	91	.540	45792	107
.216	21562	50	.281	25069	58	.346	29151	68	.411	33905	79	.476	39443	92	.541	45899	107
.217	21612	50	.282	25127	58	.347	29219	68	.412	33984	79	.477	39535	92	.542	46006	107
.218	21662	50	.283	25185	58	.348	29287	68	.413	34063	79	.478	39627	92	.543	46113	107
.219	21712	50	.284	25243	58	.349	29355	68	.414	34142	79	.479	39719	92	.544	46221	108
.220	21762	50	.285	25302	59	.350	29423	68	.415	34222	80	.480	39812	93	.545	46329	108
.221	21813	51	.286	25361	59	.351	29491	68	.416	34302	80	.481	39905	93	.546	46437	108
.222	21864	51	.287	25420	59	.352	29560	69	.417	34382	80	.482	39998	93	.547	46546	109
.223	21915	51	.288	25479	59	.353	29629	69	.418	34462	80	.483	40091	93	.548	46655	109
.224	21966	51	.289	25538	59	.354	29698	69	.419	34542	80	.484	40185	94	.549	46764	109
.225	22017	51	.290	25597	59	.355	29767	69	.420	34622	80	.485	40279	94	.550	46873	109
.226	22068	51	.291	25656	59	.356	29836	69	.421	34703	81	.486	40373	94	.551	46983	110
.227	22119	51	.292	25716	60	.357	29905	69	.422	34784	81	.487	40467	94	.552	47093	110
.228	22170	51	.293	25776	60	.358	29974	69	.423	34865	81	.488	40561	94	.553	47203	110
229	22221	51	.294	25836	60	.359	30044	70	.424	34946	81	.489	40656	95	.554	47313	110
8.230	22272	51	8.295	25896	60	8.360	30114	70	8.425	35027	81	8.490	40751	95	8 555	47424	111

TABLE I.—(Continued.)

sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.
	0.00			0.00			0.00			0.00			0.00			0.01	
8.555	47424		8.620	55207		8.685	64293		8.750	74907		8.815	87320		8.879	01614	
.556	47535	111	.621	55336	129	.686	64444	151	.751	75084	177	.816	87527	207	.880	01855	241
.557	47646	111	.622	55466	130	.687	64595	151	.752	75261	177	.817	87734	207	.881	02097	242
.558	47757	111	.623	55596	130	.688	64747	152	.753	75439	178	.818	87942	208	.882	02339	242
.559	47868	111	.624	55726	130	.689	64899	152	.754	75617	178	.819	88150	208	.883	02582	243
.560	47980	112	.625	55857	131	.690	65052	153	.755	75795	178	.820	88359	209	.884	02826	244
.561	48092	112	.626	55988	131	.691	65205	153	.756	75974	179	.821	88568	209	.885	03070	244
.562	48204	112	.627	56119	131	.692	65358	153	.757	76153	179	.822	88777	209	.886	03315	245
.563	48317	113	.628	56250	131	.693	65512	154	.758	76333	180	.823	88987	210	.887	03561	246
.564	48430	113	.629	56382	132	.694	65666	154	.759	76513	180	.824	89198	211	.888	03808	247
.565	48543	113	.630	56514	132	.695	65820	154	.760	76693	180	.825	89409	211	.889	04055	247
.566	48657	114	.631	56646	132	.696	65975	155	.761	76874	181	.826	89621	212	.890	04303	248
.567	48771	114	.632	56779	133	.697	66130	155	.762	77055	181	.827	89833	212	.891	04551	248
.568	48885	114	:633	56912	133	.698	66286	156	.763	77237	182	.828	90046	213	.892	04800	249
.569	48999	114	.634	57045	133	.699	66442	156	.764	77419	182	.829	90260	214	.893	05049	249
.570	49114	115	.635	57179	134	.700	66598	156	.765	77602	183	.830	90474	214	.894	05299	250
.571	49229	115	.636	57313	134	.701	66755	157	.766	77785	183	.831	90689	215	.895	05550	251
.572	49344	115	.637	57447	134	.702	66912	157	.767	77969	184	.832	90904	215	.896	05801	251
.573	49460	116	.638	57582	135	.703	67069	157	.768	78153	184	.833	91120	216	.897	06053	252
.574	49576	116	.639	57717	135	.704	67227	158	.769	78337	184	.834	91336	216	.898	06305	252
.575	49692	116	.640	57853	136	.705	67385	158	.770	78522	185	.835	91552	216	.899	06558	253
.576	49808	116	.641	57989	136	.706	67544	159	.771	78707	185	.836	91769	217	.900	06812	254
.577	49925	117	.642	58125	136	.707	67703	159	.772	78893	186	.837	91986	217	.901	07066	254
.578	50042	117	.643	58262	137	.708	67862	159	.773	79079	186	.838	92204	218	.902	07321	255
.579	50159	117	.644	58399	137	.709	68022	160	.774	79266	187	.839	92422	218	.903	07577	256
.580	50276	117	.645	58536	137	.710	68182	160	.775	79453	187	.840	92641	219	.904	07833	256
.581	50394	118	.646	58673	137	.711	68342	160	.776	79641	188	.841	92860	219	.905	08090	257
.582	50512	118	.647	58811	138	.712	68503	161	.777	79829	188	.842	93080	220	.906	08347	257
.583	50630	118	.648	58949	138	.713	68664	161	.778	80018	189	.843	93300	220	.907	08605	258
.584	50748	118	.649	59087	138	.714	68826	162	.779	80207	189	.844	93521	221	.908	08864	259
.585	50867	119	.650	59226	139	.715	68988	162	.780	80396	189	.845	93743	222	.909	09123	259
.586	50986	119	.651	59365	139	.716	69150	162	·781	80586	190	.846	93965	222	.910	09383	260
.587	51105	119	.652	59504	139	.717	69313	163	.782	80776	190	.847	94188	223	.911	09643	260
.588	51225	120	.653	59644	140	.718	69476	163	.783	80967	191	.848	94412	224	.912	09904	261
.589	51345	120	.654	59784	140	.719	69639	163	.784	81158	191	.849	94636	224	.913	10166	262
.590	51465	120	.655	59924	140	.720	69803	164	.785	81350	192	.850	94861	225	.914	10428	262
.591	51585	120	.656	60065	141	.721	69967	164	.786	81542	192	.851	95086	225	.915	10691	263
.592	51706	121	.657	60106	141	.722	70131	164	.787	81735	193	.852	95312	226	.916	10955	264
.593	51827	121	.658	60247	141	.723	70296	165	.788	81928	193	.853	95538	226	.917	11220	265
.594	51948	121	.659	60389	142	.724	70461	165	.789	82121	193	.854	95765	227	.918	11485	265
.595	52070	122	.660	60631	142	.725	70627	166	.790	82315	194	.855	95992	227	.919	11751	266
.596	52192	122	.661	60773	142	.726	70793	166	.791	82509	194	.856	96220	228	.920	12018	267
.597	52314	122	.662	60915	142	.727	70960	167	.792	82704	195	.857	96448	228	.921	12285	267
.598	52437	123	.663	61057	143	.728	71127	167	.793	82899	195	.858	96677	229	.922	12553	268
.599	52560	123	.664	61201	143	.729	71295	168	.794	83095	196	.859	96906	229	.923	12821	268
.600	52683	123	.665	61345	144	.730	71463	168	.795	83291	196	.860	97136	230	.924	13090	269
.601	52806	123	.666	61489	144	.731	71631	168	.796	83488	197	.861	97366	230	.925	13360	270
.602	52930	124	.667	61634	145	.732	71800	169	.797	83686	198	.862	97597	231	.926	13630	270
.603	53054	124	.668	61779	145	.733	71969	169	.798	83884	198	.863	97728	231	.927	13901	271
.604	53178	124	669	61924	145	.734	72138	169	.799	84082	198	.864	97960	232	.928	14173	272
.605	53303	125	.670	62070	146	.735	72308	170	.800	84281	199	.865	98193	233	.929	14446	273
.606	53428	125	.671	62216	146	.736	72478	170	.801	84480	199	.866	98527	234	.930	14719	273
.607	53553	125	.672	62362	146	.737	72649	171	.802	84680	200	.867	98761	234	.931	14993	274
.608	53678	125	.673	62509	147	.738	72820	171	.803	84880	200	.868	98996	235	.932	15267	274
.609	53804	126	.674	62656	147	.739	72992	172	.804	85081	201	.869	99231	235	.933	15542	275
.610	53930	126	.675	62803	147	.740	73164	172	.805	85282	201	.870	99467	236	.934	15818	276
.611	54056	126	.676	62950	147	.741	73336	172	.806	85484	202	.871	99703	236	.935	16095	277
.612	54183	127	.677	63098	148	.742	73509	173	.807	85686	202	.872	99940	237	.936	16372	277
.613	54310	127	.678	63246	148	.743	73682	173	.808	85889	203		0.01		.937	16650	278
.614	54437	127	.679	63394	148	.744	73856	174	.809	86092	203	.873	00177	237	.938	16928	278
.615	54565	128	.680	63543	149	.745	74030	174	.810	86295	203	.874	00415	238	.939	17207	279
.616	54693	128	.681	63692	149	.746	74204	174	.811	86499	204	.875	00654	239	.940	17487	280
.617	54821	128	.682	63842	150	.747	74379	175	.812	86703	204	.876	00893	239	.941	17767	280
.618	54949	128	.683	63992	150	.748	74555	176	.813	86908	205	.877	01133	240	.942	18048	281
.619	55078	129	.684	64142	150	.749	74731	176	.814	87114	206	.878	01373	240	.943	18330	282
8.620	55207	129	8.685	64293	151	8.750	74907	176	8.815	87320	206	8.879	01614	241	8.944	18613	283

TABLE I.—(CONTINUED.)

sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.	sin.$^2 g$	log. G.	Dif.
	0.01			0.01			0 01			0.01			0.02			0.02	
8.944	18613		9.009	38577		9.074	62067		9.139	89777		9.203	22006		9.268	60809	
.945	18896	283	.010	38910	333	.075	62460	393	.140	90241	464	.204	22554	548	.269	61460	651
.946	19180	284	.011	39244	334	.076	62854	394	.141	90706	465	.205	23103	549	.270	62113	653
.947	19465	285	.012	39579	335	.077	63248	394	.142	91172	466	.206	23653	550	.271	62768	655
.948	19751	286	.013	39915	336	.078	63643	395	.143	91639	467	.207	24205	552	.272	63425	657
.949	20037	286	.014	40252	337	.079	64039	396	.144	92107	468	.208	24758	553	.273	64083	658
.950	20324	287	.015	40589	337	.080	64437	398	.145	92576	469	.209	25313	555	.274	64743	660
.951	20612	288	.016	40927	338	.081	64836	399	.146	93047	471	.210	25869	556	.275	65405	662
.952	20900	288	.017	41266	339	.082	65236	400	.147	93519	472	.211	26427	558	.276	66069	664
.953	21189	289	.018	41606	340	.083	65636	400	.148	93992	473	.212	26987	560	.277	66735	666
.954	21479	290	.019	41947	341	.084	66037	401	.149	94466	474	.213	27548	561	.278	67402	667
.955	21769	290	.020	42288	341	.085	66439	402	.150	94942	476	.214	28110	562	.279	68071	669
.956	22060	291	.021	42630	342	.086	66842	403	.151	95419	477	.215	28674	564	.280	68742	671
.957	22352	292	.022	42703	343	.087	67247	405	.152	95897	478	.216	29239	565	.281	69415	673
.958	22645	293	.023	43047	344	.088	67653	406	.153	96376	479	.217	29806	567	.282	70090	675
.959	22938	293	.024	43662	345	.089	68060	407	.154	96856	480	.218	30374	568	.283	70766	676
.960	23232	294	.025	44008	346	.090	68468	408	.155	97338	482	.219	30944	570	.284	71444	678
.961	23527	295	.026	44355	347	.091	68877	409	.156	97821	483	.220	31516	572	.285	72124	680
.962	23823	296	.027	44702	347	.092	69286	409	.157	98305	484	.221	32089	573	.286	72806	682
.963	24119	296	.028	45050	348	.093	69697	411	.158	98791	486	.222	32663	574	.287	73490	684
.964	24416	297	.029	45399	349	.094	70109	412	.159	99278	487	.223	33239	576	.288	74176	686
.965	24714	298	.030	45749	350	.095	70522	413	.160	99766	488	.224	33816	577	.289	74864	688
.966	25012	298	.031	46100	351	.096	70936	414		0.02		.225	34395	579	.290	75554	690
.967	25311	299	.032	46453	353	.097	71351	415	.161	00256	490	.226	34975	580	.291	76245	691
.968	25611	300	.033	46806	353	.098	71767	416	.162	00746	490	.227	35557	582	.292	76938	693
.969	25912	301	.034	47160	354	.099	72184	417	.163	01238	492	.228	36141	584	.293	77633	695
.970	26213	301	.035	47515	355	.100	72602	418	.164	01731	493	.229	36726	585	.294	78330	697
.971	26515	302	.036	47870	355	.101	73021	419	.165	02226	495	.230	37313	587	.295	79029	699
.972	26818	303	.037	48226	356	.102	73441	420	.166	02722	496	.231	37901	588	.296	79730	701
.973	27122	304	.038	48583	357	.103	73863	422	.167	03219	497	.232	38491	590	.297	80433	703
.974	27426	304	.039	48941	358	.104	74286	423	.168	03717	498	.233	39082	591	.298	81138	705
.975	27731	305	.040	49301	360	.105	74709	423	.169	04217	500	.234	39675	593	.299	81844	706
.976	28037	306	.041	49661	360	.106	75134	425	.170	04718	501	.235	40270	595	.300	82552	708
.977	28344	307	.042	50022	361	.107	75560	426	.171	05220	502	.236	40866	596	.301	83262	710
.978	28652	308	.043	50384	362	.108	75987	427	.172	05724	504	.237	41464	598	.302	83974	712
.979	28960	308	.044	50747	363	.109	76415	428	.173	06229	505	.238	42063	599	.303	84688	714
.980	29269	309	.045	51111	364	.110	76844	429	.174	06735	506	.239	42664	601	.304	85405	717
.981	29579	310	.046	51476	365	.111	77274	430	.175	07242	507	.240	43266	602	.305	86123	718
.982	29889	310	.047	51841	365	.112	77705	431	.176	07751	509	.241	43870	604	.306	86843	720
.983	30200	311	.048	52207	366	.113	78137	432	.177	08261	510	.242	44476	606	.307	87565	722
.984	30512	312	.049	52574	367	.114	78570	433	.178	08773	512	.243	45083	607	.308	88290	725
.985	30825	313	.050	52942	368	.115	79005	435	.179	09286	513	.244	45692	609	.309	89016	726
.986	31139	314	.051	53311	369	.116	79442	436	.180	09800	514	.245	46303	611	.310	89744	728
.987	31454	315	.052	53682	371	.117	79878	436	.181	10316	516	.246	46915	612	.311	90474	730
.988	31770	316	.053	54053	371	.118	80316	438	.182	10833	517	.247	47529	614	.312	91207	733
.989	32086	316	.054	54425	372	.119	80755	439	.183	11351	518	.248	48145	616	.313	91941	734
.990	32403	317	.055	54798	373	.120	81195	440	.184	11871	520	.249	48762	617	.314	92677	736
.991	32721	318	.056	55172	374	.121	81636	441	.185	12392	521	.250	49381	619	.315	93415	738
.992	33040	319	.057	55547	375	.122	82078	442	.186	12914	522	.251	50002	621	.316	94156	741
.993	33359	319	.058	55923	376	.123	82522	444	.187	13438	524	.252	50624	622	.317	94898	742
.994	33679	320	.059	56300	377	.124	82967	445	.188	13963	525	.253	51248	624	.318	95643	745
.995	34000	321	.060	56677	377	.125	83413	446	.189	14490	527	.254	51874	626	.319	96390	747
.996	34322	322	.061	57056	379	.126	83860	447	.190	15018	528	.255	52501	627	.320	97139	749
.997	34644	322	.062	57436	380	.127	84308	448	.191	15547	529	.256	53130	629	.321	97890	751
.998	34967	323	.063	57817	381	.128	84757	449	.192	16077	530	.257	53760	630	.322	98643	753
8.999	35291	324	.064	58198	381	.129	85207	450	.193	16609	532	.258	54392	632	.323	99398	755
9.000	35616	325	.065	58581	383	.130	85659	452	.194	17142	533	.259	55026	634		0.03	
.001	35942	326	.066	58965	384	.131	86114	453	.195	17677	535	.260	55662	636	.324	00154	756
.002	36269	327	.067	59349	384	.132	86566	454	.196	18214	537	.261	56299	637	.325	00913	759
.003	36596	327	.068	59734	385	.133	87021	455	.197	18752	538	.262	56938	639	.326	01674	761
.004	36924	328	.069	60121	387	.134	87477	456	.198	19291	539	.263	57579	641	.327	02437	763
.005	37253	329	.070	60509	388	.135	87935	458	.199	19831	540	.264	58221	642	.328	03203	766
.006	37583	330	.071	60897	388	.136	88394	459	.200	20373	542	.265	58865	644	.329	03970	767
.007	37914	331	.072	61286	389	.137	88854	460	.201	20916	543	.266	59511	646	.330	04739	769
.008	38245	331	.073	61676	390	.138	89315	461	.202	21460	544	.267	60159	648	.331	05511	772
9.009	38577	332	9.074	62067	391	9.139	89777	462	9 203	22006	546	9.268	60809	650	9 332	06285	774

TABLE I.—(Continued.)

sin.^2g	log. G.	Dif.	sin.^2g	log. G.	Dif.	sin.^2g	log. G.	Dif.	sin.^2g	log. G.	Dif.	sin.^2g	log. G.	Dif.	sin.^2g	log. G.	Dif.
	0.03			0.03			0.04			0.04			0.05			0.06	
9.332	06285		9.394	58768		9.455	20394		9.517	95704		9.578	85625		9.639	95923	
.333	07061	776	.395	59693	925	.456	21499	1105	.518	97041	1337	.579	87254	1629	.640	97936	2013
.334	07839	778	.396	60620	927	.457	22607	1108	.519	98382	1341	.580	88888	1634	.641	99956	2020
.335	08619	780	.397	61550	930	.458	23719	1112	.520	99727	1345	.581	90527	1639		0.07	
.336	09402	783	.398	62483	933	.459	24835	1116		0.05		.582	92172	1645	.642	01983	2027
.337	10187	785	.399	63418	935	.460	25954	1119	.521	01077	1350	.583	93823	1651	.643	04017	2034
.338	10974	787	.400	64356	938	.461	27076	1122	.522	02431	1354	.584	95480	1657	.644	06059	2042
.339	11763	789	.401	65297	941	.462	28201	1125	.523	03789	1358	.585	97142	1662	.645	08108	2049
.340	12554	791	.402	66240	943	.463	29330	1129	.524	05151	1362	.586	98809	1667	.646	10164	2056
.341	13347	793	.403	67186	946	.464	30463	1133	.525	06517	1366		0.06		.647	12228	2064
.342	14143	796	.404	68135	949	.465	31599	1136	.526	07888	1371	.587	00482	1673	.648	14300	2072
.343	14941	798	.405	69087	952	.466	32738	1139	.527	09263	1375	.588	02161	1679	.649	16379	2079
.344	15741	800	.406	70041	954	.467	33881	1143	.528	10643	1380	.589	03845	1684	.650	18466	2087
.345	16543	802	.407	70998	957	.468	35027	1146	.529	12027	1384	.590	05535	1690	.651	20560	2094
.346	17348	805	.408	71958	960	.469	36177	1150	.530	13415	1388	.591	07231	1696	.652	22662	2102
.347	18155	807	.409	72921	963	.470	37330	1153	.531	14808	1393	.592	08932	1701	.653	24772	2110
.348	18964	809	.410	73887	966	.471	38487	1157	.532	16206	1398	.593	10639	1707	.654	26890	2118
.349	19775	811	.411	74855	968	.472	39647	1160	.533	17608	1402	.594	12352	1713	.655	29015	2125
.350	20589	814	.412	75826	971	.473	40811	1164	.534	19014	1406	.595	14071	1719	.656	31148	2133
.351	21405	816	.413	76800	974	.474	41978	1167	.535	20425	1411	.596	15796	1725	.657	33289	2141
.352	22224	819	.414	77777	977	.475	43148	1170	.536	21841	1416	.597	17527	1731	.658	35438	2149
.353	23045	821	.415	78757	980	.476	44322	1174	.537	23261	1420	.598	19264	1737	.659	37595	2157
.354	23868	823	.416	79739	982	.477	45500	1178	.538	24685	1424	.599	21007	1743	.660	39761	2166
.355	24693	825	.417	80724	985	.478	46681	1181	.539	26114	1429	.600	22755	1748	.661	41935	2174
.356	25520	827	.418	81712	988	.479	47866	1185	.540	27548	1434	.601	24509	1754	.662	44117	2182
.357	26350	830	.419	82703	991	.480	49055	1189	.541	28986	1438	.602	26270	1761	.663	46306	2189
.358	27182	832	.420	83697	994	.481	50248	1193	.542	30429	1443	.603	28037	1767	.664	48504	2198
.359	28017	835	.421	84694	997	.482	51444	1196	.543	31876	1447	.604	29810	1773	.665	50710	2206
.360	28854	837	.422	85694	1000	.483	52643	1199	.544	33328	1452	.605	31589	1779	.666	52924	2214
.361	29693	839	.423	86697	1003	.484	53846	1203	.545	34785	1457	.606	33374	1785	.667	55147	2223
.362	30535	842	.424	87702	1005	.485	55053	1207	.546	36247	1462	.607	35165	1791	.668	57378	2231
.363	31379	844	.425	88710	1008	.486	56263	1210	.547	37713	1466	.608	36963	1798	.669	59617	2239
.364	32225	846	.426	89722	1012	.487	57477	1214	.548	39184	1471	.609	38767	1804	.670	61865	2248
.365	33074	849	.427	90737	1015	.488	58695	1218	.549	40660	1476	.610	40577	1810	.671	64121	2286
.366	33926	852	.428	91754	1017	.489	59917	1222	.550	42140	1480	.611	42393	1816	.672	66386	2265
.367	34779	853	.429	92774	1020	.490	61142	1225	.551	43625	1485	.612	44215	1822	.673	68659	2273
.368	35635	856	.430	93797	1023	.491	62371	1229	.552	45116	1491	.613	46044	1829	.674	70941	2282
.369	36494	859	.431	94824	1027	.492	63604	1233	.553	46611	1495	.614	47879	1835	.675	73232	2291
.370	37355	861	.432	95854	1030	.493	64841	1237	.554	48111	1500	.615	49720	1841	.676	75532	2300
.371	38218	863	.433	96886	1032	.494	66082	1241	.555	49616	1505	.616	51568	1848	.677	77840	2308
.372	39084	866	.434	97922	1036	.495	67327	1245	.556	51125	1509	.617	53423	1855	.678	80157	2317
.373	39953	869	.435	98961	1039	.496	68575	1248	.557	52639	1514	.618	55284	1861	.679	82483	2326
.374	40824	871		0 04		.497	69827	1252	.558	54158	1519	.619	57151	1867	.680	84818	2335
.375	41697	873	.436	00003	1042	.498	71083	1256	.559	55683	1525	.620	59025	1874	.681	87162	2344
.376	42572	875	.437	01048	1045	.499	72343	1260	.560	57213	1530	.621	60906	1881	.682	89515	2353
.377	43450	878	.438	02096	1048	.500	73607	1264	.561	58747	1534	.622	62793	1887	.683	91877	2362
.378	44331	881	.439	03147	1051	.501	74875	1268	.562	60286	1539	.623	64687	1894	.684	94249	2372
.379	45214	883	.440	04201	1054	.502	76147	1272	.563	61831	1545	.624	66588	1901	.685	96630	2381
.380	46099	885	.441	05258	1057	.503	77423	1276	.564	63381	1550	.625	68496	1908	.686	99020	2390
.381	46987	888	.442	06318	1060	.504	78702	1279	.565	64936	1555	.626	70410	1914		0.08	
.382	47877	890	.443	07382	1064	.505	79985	1283	.566	66496	1560	.627	72331	1921	.687	01419	2399
.383	48770	893	.444	08449	1067	.506	81272	1287	.567	68061	1565	.628	74258	1927	.688	03827	2408
.384	49666	896	.445	09519	1070	.507	82564	1292	.568	69632	1571	.629	76192	1934	.689	06245	2418
.385	50564	898	.446	10592	1073	.508	83860	1296	.569	71208	1576	.630	78133	1941	.690	08672	2427
.386	51465	901	.447	11668	1076	.509	85160	1300	.570	72789	1581	.631	80082	1949	.691	11108	2436
.387	52369	904	.448	12747	1079	.510	86464	1304	.571	74375	1586	.632	82038	1956	.692	13554	2446
.388	53275	906	.449	13829	1082	.511	87771	1307	.572	75966	1591	.633	84001	1963	.693	16009	2455
.389	54184	909	.450	14915	1086	.512	89082	1311	.573	77562	1596	.634	85970	1969	.694	18475	2466
.390	55096	912	.451	16004	1089	.513	90397	1315	.574	79164	1602	.635	87946	1976	.695	20951	2476
.391	56010	914	.452	17097	1093	.514	91717	1320	.575	80771	1607	.636	89930	1984	.696	23436	2485
.392	56927	917	.453	18193	1096	.515	93042	1325	.576	82384	1613	.637	91920	1990	.697	25930	2494
.393	57846	919	.454	19292	1099	.516	94371	1329	.577	84002	1618	.638	93918	1998	.698	28435	2505
9.394	58768	922	9.455	20304	1102	9.517	95704	1333	9.578	85625	1623	9.639	95923	2005	9.699	30951	2516

TABLE II.

$\tan.^2 h$	log. G H.	Dif.	$\tan.^2 h$	log. G H.	Dif.	$\tan.^2 h$	log. G H.	Dif.	$\tan.^2 h$	log. G H.	Dif.	$\tan.^2 h$	log. G H.	Dif.	$\tan.^2 h$	log. G H.	Dif.
	0.00000			.0000			.0000			.0000			.000			.000	
7.00	01		8.09	152		8.27	349		8.45	799		8.63	1829		8.81	4195	
.10	02	1	.10	159	7	.28	365	16	.46	837	38	.64	1915	86	.82	4394	199
.20	03	1	.11	167	8	.29	382	17	.47	876	39	.65	2006	91	.83	4603	209
.30	04	1	.12	176	9	.30	400	18	.48	917	41	.66	2101	95	.84	4820	217
.40	06	2	.13	185	9	.31	419	19	.49	960	43	.67	2200	99	.85	5047	227
.50	10	4	.14	193	8	.32	439	20	.50	1006	46	.68	2304	104	.86	5285	238
.60	16	6	.15	202	9	.33	460	21	.51	1053	47	.69	2413	109	.87	5535	250
.70	25	9	.16	210	8	.34	482	22	.52	1103	50	.70	2528	115	.88	5795	260
.80	40	15	.17	220	10	.35	504	22	.53	1156	53	.71	2648	120	.89	6069	274
7.90	62	22	.18	230	10	.36	527	23	.54	1210	54	.72	2772	124	.90	6356	287
8.00	100	38	.19	241	11	.37	552	25	.55	1266	56	.73	2901	129	.91	6657	301
.01	105	5	.20	253	12	.38	578	26	.56	1325	59	.74	3038	137	.92	6972	315
.02	109	4	.21	265	12	.39	605	27	.57	1387	62	.75	3182	144	.93	7301	329
.03	114	5	.22	277	12	.40	634	29	.58	1453	66	.76	3333	151	.94	7647	346
.04	120	6	.23	290	13	.41	664	30	.59	1522	69	.77	3490	157	.95	8008	361
.05	126	6	.24	304	14	.42	695	31	.60	1593	71	.78	3655	165	.96	8386	378
.06	132	6	.25	319	15	.43	728	33	.61	1668	75	.79	3827	172	.97	8781	395
.07	138	6	.26	334	15	.44	762	34	.62	1747	79	.80	4007	180	.98	9196	415
.08	145	7	8.27	349	15	8.45	799	37	8.63	1829	82	8.81	4195	188	8.99	9633	437
8.09	152	7															

TABLE III.

log. a.	log. $\frac{1}{y''}$	Dif.	log. a.	log. $\frac{1}{y''}$	Dif.	log. a.	log. $\frac{1}{y''}$	Dif.	log. a.	log. $\frac{1}{y''}$	Dif.	log. a.	log. $\frac{1}{y''}$	Dif.	log. a.	log. $\frac{1}{y''}$	Dif.
	9.999			9.999			9.999			9.999			9.999			9.999	
8.00	9928		8.33	9669		8.660	8487		8.774	7441		8.807	7019		8.840	6529	
.01	9925	3	.34	9653	16	.670	8416	71	.775	7429	12	.808	7006	13	.841	6513	16
.02	9921	4	.35	9637	16	.680	8341	75	.776	7417	12	.809	6992	14	.842	6497	16
.03	9917	4	.36	9620	17	.690	8263	78	.777	7405	12	.810	6978	14	.843	6481	16
.04	9913	4	.37	9602	18	.700	8181	82	.778	7393	12	.811	6964	14	.844	6465	16
.05	9909	4	.38	9583	19	.710	8096	85	.779	7381	12	.812	6950	14	.845	6449	16
.06	9904	5	.39	9563	20	.720	8006	90	.780	7369	12	.813	6936	14	.846	6432	17
.07	9900	4	.40	9542	21	.730	7912	94	.781	7357	12	.814	6922	14	.847	6416	16
.08	9895	5	.41	9520	22	.740	7813	99	.782	7345	12	.815	6908	14	.848	6399	17
.09	9890	5	.42	9497	23	.750	7709	104	.783	7333	12	.816	6893	15	.849	6383	17
.10	9885	5	.43	9474	23	.751	7699	10	.784	7321	12	.817	6879	14	.850	6366	17
.11	9880	5	.44	9450	24	.752	7689	10	.785	7308	13	.818	6864	15	.851	6349	17
.12	9874	6	.45	9425	25	.753	7678	11	.786	7296	12	.819	6850	14	.852	6332	17
.13	9868	6	.46	9398	27	.754	7667	11	.787	7283	13	.820	6835	15	.853	6315	17
.14	9862	6	.47	9369	29	.755	7656	11	.788	7271	12	.821	6821	14	.854	6298	17
.15	9855	7	.48	9339	30	.756	7645	11	.789	7258	13	.822	6806	15	.855	6281	17
.16	9848	7	.49	9308	31	.757	7634	11	.790	7245	13	.823	6791	15	.856	6264	17
.17	9841	7	.50	9276	32	.758	7623	11	.791	7232	13	.824	6776	15	.857	6247	17
.18	9833	8	.51	9242	34	.759	7612	11	.792	7219	13	.825	6761	15	.858	6230	17
.19	9825	8	.52	9206	36	.760	7601	11	.793	7206	13	.826	6746	15	.859	6212	18
.20	9817	8	.53	9169	37	.761	7590	11	.794	7193	13	.827	6731	15	.860	6195	17
.21	9808	9	.54	9130	39	.762	7579	11	.795	7180	13	.828	6716	15	.861	6177	18
.22	9800	8	.55	9089	41	.763	7567	12	.796	7167	13	.829	6701	15	.862	6159	18
.23	9791	9	.56	9046	43	.764	7556	11	.797	7154	13	.830	6686	15	.863	6141	18
.24	9781	10	.57	9001	45	.765	7545	11	.798	7141	13	.831	6671	15	.864	6123	18
.25	9771	10	.58	8954	47	.766	7533	12	.799	7128	13	.832	6656	15	.865	6105	18
.26	9760	11	.59	8905	49	.767	7522	11	.800	7114	14	.833	6640	16	.866	6087	18
.27	9749	11	.60	8853	52	.768	7510	12	.801	7100	14	.834	6625	15	.867	6069	18
.28	9737	12	.61	8799	54	.769	7499	11	.802	7087	13	.835	6609	16	.868	6051	18
.29	9725	12	.62	8742	57	.770	7487	12	.803	7073	14	.836	6593	16	.869	6033	18
.30	9712	13	.63	8682	60	.771	7476	11	.804	7060	13	.837	6577	16	.870	6015	18
.31	9698	14	.64	8620	62	.772	7464	12	.805	7046	14	.838	6561	16	.871	5996	19
.32	9684	14	.65	8555	65	.773	7453	11	.806	7033	13	.839	6545	16	.872	5978	18
8.33	9669	15	8.66	8487	68	8.774	7441	12	8.807	7019	14	8 840	6529	16	8.873	5959	19

TABLE III.—(CONTINUED.)

log. a.	log. $\frac{1}{\mathbf{y}''}$	Dif.	log. a.	log. $\frac{1}{\mathbf{y}''}$	Dif.	log. a.	log. $\frac{1}{\mathbf{y}''}$	Dif.	log. a.	log. $\frac{1}{\mathbf{y}''}$	Dif.	log. a.	log. $\frac{1}{\mathbf{y}''}$	Dif.	log. a.	log. $\frac{1}{\mathbf{y}''}$	Dif.
	9.999			9.999			9.999			9.999			9.998			9.998	
8.873	5959		8.938	4546		9.003	2636		9.068	0055		9.132	6625		9.197	1919	
.874	5941	18	.939	4521	25	.004	2602	34	.069	0009	46	.133	6563	62	.198	1835	84
.875	5922	19	.940	4495	26	.005	2568	34		9.998		.134	6501	62	.199	1750	85
.876	5903	19	.941	4470	25	.006	2533	35	.070	9962	47	.135	6438	63	.200	1665	85
.877	5884	19	.942	4444	26	.007	2499	34	.071	9916	46	.136	6376	62	.201	1580	85
.878	5865	19	.943	4419	25	.008	2464	35	.072	9869	47	.137	6313	63	.202	1494	86
.879	5846	19	.944	4393	26	.009	2429	35	.073	9822	47	.138	6249	64	.203	1408	86
.880	5827	19	.945	4367	26	.010	2394	35	.074	9775	47	.139	6185	64	.204	1321	87
.881	5808	19	.946	4341	26	.011	2359	35	.075	9727	48	.140	6120	65	.205	1234	87
.882	5789	19	.947	4315	26	.012	2323	36	.076	9680	47	.141	6056	64	.206	1147	87
.883	5769	20	.948	4288	27	.013	2288	35	.077	9632	48	.142	5991	65	.207	1059	88
.884	5750	19	.949	4262	26	.014	2252	36	.078	9584	48	.143	5926	65	.208	0971	88
.885	5730	20	.950	4235	27	.015	2216	36	.079	9536	48	.144	5861	65	.209	0882	89
.886	5710	20	.951	4209	26	.016	2180	36	.080	9487	49	.145	5795	66	.210	0793	89
.887	5690	20	.952	4182	27	.017	2144	36	.081	9439	48	.146	5729	66	.211	0703	90
.888	5670	20	.953	4155	27	.018	2107	37	.082	9390	49	.147	5663	66	.212	0613	90
.889	5650	20	.954	4128	27	.019	2071	36	.083	9340	50	.148	5596	67	.213	0523	90
.890	5630	20	.955	4101	27	.020	2034	37	.084	9291	49	.149	5528	68	.214	0432	91
.891	5609	21	.956	4074	27	.021	1997	37	.085	9241	50	.150	5461	67	.215	0341	91
.892	5589	20	.957	4046	28	.022	1960	37	.086	9191	50	.151	5393	68	.216	0249	92
.893	5568	21	.958	4019	27	.023	1923	37	.087	9140	51	.152	5326	67	.217	0157	92
.894	5548	20	.959	3991	28	.024	1885	38	.088	9090	50	.153	5258	68	.218	0065	92
.895	5527	21	.960	3963	28	.025	1848	37	.089	9039	51	.154	5190	68		9.997	
.896	5507	20	.961	3935	28	.026	1810	38	.090	8988	51	.155	5121	69	.219	9972	93
.897	5486	21	.962	3907	28	.027	1772	38	.091	8937	51	.156	5051	70	.220	9879	93
.898	5465	21	.963	3879	28	.028	1734	38	.092	8885	52	.157	4982	69	.221	9785	94
.899	5444	21	.964	3850	29	.029	1696	38	.093	8834	51	.158	4912	70	.222	9691	94
.900	5423	21	.965	3822	28	.030	1658	38	.094	8782	52	.159	4842	70	.223	9596	95
.901	5402	21	.966	3793	29	.031	1619	39	.095	8730	52	.160	4771	71	.224	9501	95
.902	5381	21	.967	3765	28	.032	1580	39	.096	8677	53	.161	4701	70	.225	9405	96
.903	5359	22	.968	3736	29	.033	1541	39	.097	8625	52	.162	4630	71	.226	9309	96
.904	5338	21	.969	3707	29	.034	1501	40	.098	8572	53	.163	4558	72	.227	9213	96
.905	5316	22	.970	3678	29	.035	1462	39	.099	8519	53	.164	4487	71	.228	9116	97
.906	5294	22	.971	3648	30	.036	1422	40	.100	8466	53	.165	4415	72	.229	9019	97
.907	5272	22	.972	3619	29	.037	1383	39	.101	8412	54	.166	4342	73	.230	8921	98
.908	5250	22	.973	3589	30	.038	1343	40	.102	8359	53	.167	4270	72	.231	8823	98
.909	5228	22	.974	3560	29	.039	1303	40	.103	8305	54	.168	4197	73	.232	8724	99
.910	5206	22	.975	3530	30	.040	1263	40	.104	8251	54	.169	4123	74	.233	8625	99
.911	5184	22	.976	3500	30	.041	1222	41	.105	8196	55	.170	4048	75	.234	8525	100
.912	5162	22	.977	3470	30	.042	1182	40	.106	8142	54	.171	3974	74	.235	8425	100
.913	5139	23	.978	3440	30	.043	1142	41	.107	8087	55	.172	3899	75	.236	8324	101
.914	5117	22	.979	3410	30	.044	1101	41	.108	8032	55	.173	3824	75	.237	8223	101
.915	5094	23	.980	3379	31	.045	1061	41	.109	7976	56	.174	3749	75	.238	8121	102
.916	5072	22	.981	3349	30	.046	1019	42	.110	7921	55	.175	3673	76	.239	8019	102
.917	5049	23	.982	3318	31	.047	0978	41	.111	7865	56	.176	3597	76	.240	7917	102
.918	5026	23	.983	3287	31	.048	0936	42	.112	7808	57	.177	3520	77	.241	7814	103
.919	5003	23	.984	3256	31	.049	0894	42	.113	7752	56	.178	3444	76	.242	7710	104
.920	4980	23	.985	3225	31	.050	0850	42	.114	7695	57	.179	3367	77	.243	7606	104
.921	4957	23	.986	3193	32	.051	0807	43	.115	7638	57	.180	3290	77	.244	7502	104
.922	4934	23	.987	3162	31	.052	0765	42	.116	7580	58	.181	3212	78	.245	7397	105
.923	4911	23	.988	3130	32	.053	0722	43	.117	7523	57	.182	3135	77	.246	7292	105
.924	4887	24	.989	3098	32	.054	0679	43	.118	7465	58	.183	3057	78	.247	7186	106
.925	4864	23	.990	3066	32	.055	0636	43	.119	7407	58	.184	2978	79	.248	7080	106
.926	4840	24	.991	3034	32	.056	0592	44	.120	7348	59	.185	2899	79	.249	6973	107
.927	4816	24	.992	3001	33	.057	0549	43	.121	7290	58	.186	2819	80	.250	6866	107
.928	4792	24	.993	2969	32	.058	0505	44	.122	7231	59	.187	2739	80	.251	6758	108
.929	4768	24	.994	2936	33	.059	0461	44	.123	7172	59	.188	2658	81	.252	6650	108
.930	4744	24	.995	2903	33	.060	0416	45	.124	7112	60	.189	2578	80	.253	6541	109
.931	4720	24	.996	2870	33	.061	0372	44	.125	7052	60	.190	2497	81	.254	6432	109
.932	4695	25	.997	2837	33	.062	0327	45	.126	6991	61	.191	2415	82	.255	6322	110
.933	4671	24	.998	2804	33	.063	0282	45	.127	6931	60	.192	2334	81	.256	6211	111
.934	4646	25	8.999	2770	34	.064	0237	45	.128	6870	61	.193	2252	82	.257	6100	111
.935	4621	25	9.000	2737	33	.065	0192	45	.129	6809	61	.194	2169	83	.258	5988	112
.936	4596	25	.001	2703	34	.066	0146	46	.130	6748	61	.195	2086	83	.259	5877	111
.937	4571	25	.002	2670	33	.067	0101	45	.131	6686	62	.196	2002	84	.260	5764	113
8.938	4546	25	9.003	2636	34	9.068	0055	46	9.132	6625	61	9.197	1919	83	9.261	5651	113

TABLE III.—(CONTINUED.)

log. a.	log. $\frac{1}{y''}$	Dif.	log. a.	log. $\frac{1}{y''}$	Dif.	log. a.	log. $\frac{1}{y''}$	Dif.	log. a.	log $\frac{1}{y''}$	Dif.	log. a.	log. $\frac{1}{y''}$	Dif.	log. a.	log. $\frac{1}{y''}$	Dif.
	9.997			9.996			9.99			9.99			9.99			9.99	
9.261	5651		9.317	8383		9.373	58903		9.430	46260		9.487	29599		9.544	07552	
.262	5537	114	.318	8235	148	.374	58710	193	.431	46006	254	.488	29263	336	.545	07107	445
.263	5423	114	.319	8086	149	.375	58516	194	.432	45751	255	.489	28926	337	.546	06659	448
.264	5308	115	.320	7937	149	.376	58321	195	.433	45494	257	.490	28587	339	.547	06209	450
.265	5193	115	.321	7787	150	.377	58125	196	.434	45236	258	.491	28246	341	.548	05757	452
.266	5077	116	.322	7636	151	.378	57927	198	.435	44977	259	.492	27904	342	.549	05303	454
.267	4961	116	.323	7484	152	.379	57729	198	.436	44716	261	.493	27560	344	.550	04847	456
.268	4844	117	.324	7332	152	.380	57530	199	.437	44454	262	.494	27214	346	.551	04388	459
.269	4727	117	.325	7179	153	.381	57330	200	.438	44191	263	.495	26867	347	.552	03927	461
.270	4609	118	.326	7025	154	.382	57129	201	.439	43926	265	.496	26518	349	.553	03463	464
.271	4491	118	.327	6870	155	.383	56928	201	.440	43660	266	.497	26167	351	.554	02997	466
.272	4372	119	.328	6715	155	.384	56725	203	.441	43393	267	.498	25814	353	.555	02529	468
.273	4252	120	.329	6559	156	.385	56521	204	.442	43125	268	.499	25459	355	.556	02059	470
.274	4132	120	.330	6402	157	.386	56316	205	.443	42856	269	.500	25103	356	.557	01586	473
.275	4011	121	.331	6245	157	.387	56110	206	.444	42585	271	.501	24745	358	.558	01111	475
.276	3889	122	.332	6087	158	.388	55904	206	.445	42313	272	.502	24385	360	.559	00633	478
.277	3767	122	.333	5928	159	.389	55696	208	.446	42040	273	.503	24024	361	.560	00153	480
.278	3644	123	.334	5768	160	.390	55487	209	.447	41765	275	.504	23661	363		9.98	
.279	3521	123	.335	5607	161	.391	55277	210	.448	41489	276	.505	23296	365	.561	99671	482
.280	3397	124	.336	5446	161	.392	55066	211	.449	41211	278	.506	22929	367	.562	99186	485
.281	3273	124	.337	5284	162	.393	54855	211	.450	40932	279	.507	22560	369	.563	98699	487
.282	3148	125	.338	5121	163	.394	54642	213	.451	40652	280	.508	22190	370	.564	98209	490
.283	3022	126	.339	4957	164	.395	54428	214	.452	40370	282	.509	21818	372	.565	97717	492
.284	2896	126	.340	4792	165	.396	54213	215	.453	40087	283	.510	21444	374	.566	97222	495
.285	2769	127	.341	4627	165	.397	53998	215	.454	39803	284	.511	21068	376	.567	96724	498
.286	2642	127	.342	4461	166	.398	53781	217	.455	39517	286	.512	20690	378	.568	96224	500
.237	2514	128	.343	4294	167	.399	53563	218	.456	39230	287	.513	20310	380	.569	95721	503
.288	2386	128	.344	4126	168	.400	53344	219	.457	38941	289	.514	19928	382	.570	95216	505
.289	2257	129	.345	3958	168	.401	53124	220	.458	38651	290	.515	19545	383	.571	94708	508
.290	2127	130	.346	3789	169	.402	52903	221	.459	38360	291	.516	19160	385	.572	94198	510
.291	1997	130	.347	3619	170	.403	52681	222	.460	38067	293	.517	18773	387	.573	93685	513
.292	1866	131	.348	3448	171	.404	52458	223	.461	37773	294	.518	18384	389	.574	93170	515
.293	1734	132	.349	3276	172	.405	52234	224	.462	37477	296	.519	17993	391	.575	92652	518
.294	1602	132	.350	3104	172	.406	52009	225	.463	37180	297	.520	17600	393	.576	92131	521
.295	1469	133	.351	2931	173	.407	51783	226	.464	36881	299	.521	17205	395	.577	91608	523
.296	1335	134	.352	2757	174	.408	51555	228	.465	36581	300	.522	16808	397	.578	91082	526
.297	1201	134	.353	2582	175	.409	51326	229	.466	36280	301	.523	16409	399	.579	90553	529
.298	1066	135	.354	2406	176	.410	51096	230	.467	35977	303	.524	16008	401	.580	90022	531
.299	0931	135	.355	2229	177	.411	50865	231	.468	35673	304	.525	15605	403	.581	89488	534
.300	0795	136	.356	2052	177	.412	50633	232	.469	35367	306	.526	15200	405	.582	88951	537
.301	0659	136	.357	1874	178	.413	50400	233	.470	35060	307	.527	14793	407	.583	88411	540
.302	0522	137	.358	1695	179	.414	50166	234	.471	34751	309	.528	14384	409	.584	87869	542
.303	0384	138	.359	1515	180	.415	49931	235	.472	34441	310	.529	13973	411	.585	87324	545
.304	0246	138	.360	1334	181	.416	49695	236	.473	34129	312	.530	13559	414	.586	86776	548
.305	0107	139	.361	1153	181	.417	49457	238	.474	33816	313	.531	13144	415	.587	86225	551
	9.996		.362	0971	182	.418	49218	239	.475	33501	315	.532	12727	417	.588	85671	554
.306	9967	140	.363	0788	183	.419	48978	240	.476	33185	316	.533	12308	419	.589	85115	556
.307	9826	141	.364	0604	184	.420	48737	241	.477	32867	318	.534	11887	421	.590	84556	559
.308	9685	141	.365	0419	185	.421	48495	242	.478	32547	320	.535	11463	424	.591	83993	563
.309	9543	142	.366	0233	186	.422	48252	243	.479	32226	321	.536	11037	426	.592	83428	565
.310	9400	143	.367	0146	187	.423	48007	245	.480	31903	323	.537	10609	428	.593	82860	568
.311	9257	143		9.995		.424	47761	246	.481	31579	324	.538	10179	430	.594	82289	571
.312	9113	144	.368	9858	188	.425	47514	247	.482	31253	326	.539	09747	432	.595	81716	573
.313	8968	145	.369	9668	190	.426	47266	248	.483	30925	328	.540	09312	435	.596	81139	577
.314	8823	145	.370	9478	190	.427	47016	250	.484	30596	329	.541	08875	437	.597	80560	579
.315	8677	146	.371	9287	191	.428	46765	251	.485	30265	331	.542	08436	439	.598	79978	582
.316	8530	147	.372	9095	192	.429	46513	252	.486	29933	332	.543	07995	441	.599	79393	585
9 317	8383	147	9.373	8903	192	9.430	46260	253	9.487	29599	334	9.544	07552	443	9 600	78805	588

TABLE IV.

$\log. \frac{r''}{(r+r')^{\frac{3}{2}}}$	$\log. \frac{3-q''}{3\sqrt{2}}$	Dif.	$\log. \frac{r''}{(r+r')^{\frac{3}{2}}}$	$\log. \frac{3-q''}{3\sqrt{2}}$	Dif.	$\log. \frac{r''}{(r+r')^{\frac{3}{2}}}$	$\log. \frac{3-q''}{3\sqrt{2}}$	Dif.	$\log. \frac{r''}{(r+r')^{\frac{3}{2}}}$	$\log. \frac{3-q''}{3\sqrt{2}}$	Dif.
	9.849			9.849			9.848			9.848	
7.00	4847		8.530	1520		8.655	8918		8.718	6914	
.10	4845	2	.540	1362	158	.656	9891	27	.719	6877	37
.20	4842	3	.550	1197	165	.657	9863	28	.720	6840	37
.30	4838	4	.560	1025	172	.658	9836	27	.721	6803	37
.40	4831	7	.570	0844	181	.659	9808	28	.722	6766	37
.50	4820	11	.580	0655	189	.660	8780	28	.723	6728	38
.60	4803	17	.590	0457	198	.661	8752	28	.724	6691	37
.70	4776	27	.600	0249	208	662	8723	29	.725	6653	38
.80	4735	41	.601	0228	21	.663	8695	28	.726	6615	38
7.90	4667	68	.602	0206	22	.664	8666	29	.727	6577	38
8.00	4560	107	.603	0185	21	.665	8638	28	.728	6538	39
.01	4547	13	.604	0163	22	.666	8609	29	.729	6499	39
.02	4533	14	.605	0141	22	.667	8580	29	.730	6460	39
.03	4518	15	.606	0119	22	.668	8551	29	.731	6421	39
.04	4502	16	.607	0098	21	.669	8522	29	.732	6382	39
.05	4485	17	.608	0076	22	.670	8493	29	.733	6342	40
.06	4468	17	.609	0054	22	.671	8463	30	.734	6303	39
.07	4450	18	.610	0032	22	.672	8434	29	.735	6263	40
.08	4432	18	.611	0009	23	.673	8404	30	.736	6223	40
.09	4412	20		9.848		.674	8374	30	.737	6183	40
.10	4391	21	.612	9987	22	.675	8344	30	.738	6143	40
.11	4369	22	.613	9964	23	.676	8314	30	.739	6102	41
.12	4347	22	.614	9941	23	.677	8284	30	.740	6062	40
.13	4323	24	.615	9919	22	.678	8253	31	.741	6021	41
.14	4298	25	.616	9896	23	.679	8223	30	.742	5980	41
.15	4272	26	.617	9873	23	.680	8192	31	.743	5938	42
.16	4245	27	.618	9850	23	.681	8161	31	.744	5897	41
.17	4216	29	.619	9827	23	.682	8130	31	.745	5855	42
.18	4186	30	.620	9804	23	.683	8099	31	.746	5813	42
.19	4155	31	.621	9780	24	.684	8067	32	.747	5771	42
.20	4123	32	.622	9757	23	.685	8036	31	.748	5729	42
.21	4089	34	.623	9733	24	.686	8004	32	.749	5687	42
.22	4053	36	.624	9709	24	.687	7973	31	.750	5645	42
.23	4015	38	.625	9686	23	.688	7941	32	.751	5602	43
.24	3975	40	.626	9662	24	.689	7909	32	.752	5559	43
.25	3934	41	.627	9638	24	.690	7877	32	.753	5516	43
.26	3891	43	.628	9614	24	.691	7845	32	.754	5473	43
.27	3846	45	.629	9590	24	.692	7813	32	.755	5450	43
.28	3799	47	.630	9566	24	.693	7780	33	.756	5386	44
.29	3749	50	.631	9541	25	.694	7748	32	.757	5342	44
.30	3697	52	.632	9517	24	.695	7715	33	.758	5298	44
.31	3642	55	.633	9492	25	.696	7682	33	.759	5253	45
.32	3585	57	.634	9467	25	.697	7649	33	.760	5209	44
.33	3525	60	.635	9442	25	.698	7615	34	.761	5164	45
.34	3463	62	.636	9417	25	.699	7581	34	.762	5119	45
.35	3398	65	.637	9392	25	.700	7547	34	.763	5074	45
.36	3329	69	.638	9367	25	.701	7513	34	.764	5028	46
.37	3257	72	.639	9341	26	.702	7478	35	.765	4983	45
.38	3182	75	.640	9316	25	.703	7444	34	.766	4937	46
.39	3103	79	.641	9290	26	.704	7409	35	.767	4891	46
.40	3021	82	.642	9265	25	.705	7375	34	.768	4845	46
.41	2935	86	.643	9239	26	.706	7340	35	.769	4798	47
.42	2844	91	.644	9213	26	.707	7307	35	.770	4752	46
.43	2749	95	.645	9187	26	.708	7274	35	.771	4705	47
.44	2651	98	.646	9161	26	.709	7237	35	.772	4658	47
.45	2548	103	.647	9134	27	.710	7202	35	.773	4611	47
.46	2439	109	.648	9108	26	.711	7166	36	.774	4563	48
.47	2325	114	.649	9081	27	.712	7131	35	.775	4516	47
.48	2205	120	.650	9054	27	.713	7095	36	.776	4468	48
.49	2080	125	.651	9027	27	.714	7059	36	.777	4420	48
.50	1949	131	.652	9000	27	.715	7023	36	.778	4371	49
.51	1813	136	.653	8973	27	.716	6987	36	.779	4322	49
.52	1670	143	.654	8946	27	.717	6950	37	.780	4273	49
8 53	1520	150	8.655	8918	28	8.718	6914	36	8.781	4224	49

TABLE IV.—(CONTINUED.)

$\log. \frac{\tau''}{(r+r')^{\frac{3}{2}}}$	$\log. \frac{3-q''}{3\sqrt{2}}$	Dif.	$\log. \frac{\tau''}{(r+r')^{\frac{3}{2}}}$	$\log. \frac{3-q''}{3\sqrt{2}}$	Dif.	$\log. \frac{\tau''}{(r+r')^{\frac{3}{2}}}$	$\log. \frac{3-q''}{3\sqrt{2}}$	Dif.	$\log. \frac{\tau''}{(r+r')^{\frac{3}{2}}}$	$\log. \frac{3-q''}{3\sqrt{2}}$	Dif.
	9 848			9.848			9.847			9.84	
8.781	4224		8.846	0486		8.910	5507		8.975	68655	
.782	4174	50	.847	0419	67	.911	5417	90	.976	68532	123
.783	4125	49	.848	0351	68	.912	5326	91	.977	68408	124
.784	4075	50	.849	0284	67	.913	5235	91	.978	68284	124
.785	4025	50	.850	0216	68	.914	5143	92	.979	68159	125
.786	3975	50	.851	0148	68	.915	5051	92	.980	68034	125
.787	3924	51	.852	0079	69	.916	4958	93	.981	67908	126
.788	3874	50	.853	0011	68	.917	4866	92	.982	67781	127
.789	3823	51		9 847		.918	4773	93	.983	67654	127
.790	3772	51	.854	9942	69	.919	4679	94	.984	67527	127
.791	3720	52	.855	9873	69	.920	4585	94	.985	67399	128
.792	3664	51	.856	9803	70	.921	4491	94	.986	67270	129
.793	3617	52	.857	9733	70	.922	4396	95	.987	67141	129
.794	3565	52	.858	9662	71	.923	4301	95	.988	67011	130
.795	3513	52	.859	9591	71	.924	4205	96	.989	66886	131
.796	3460	53	.860	9520	71	.925	4108	97	.990	66749	131
.797	3407	53	.861	9449	71	.926	4011	97	.991	66617	132
.798	3354	53	.862	9377	72	.927	3914	97	.992	66485	132
.799	3300	54	.863	9305	72	.928	3816	98	.993	66352	133
.800	3247	53	.864	9233	72	.929	3717	99	.994	66218	134
.801	3193	54	.865	9160	73	.930	3618	99	.995	66084	134
.802	3139	54	.866	9087	73	.931	3518	100	.996	65949	135
.803	3084	55	.867	9013	74	.932	3418	100	.997	65813	136
.804	3030	54	.868	8940	73	.933	3317	101	.998	65677	136
.805	2975	55	.869	8866	74	.934	3217	100	8.999	65540	137
.806	2920	55	.870	8792	74	.935	3116	101	9.000	65402	138
.807	2864	56	.871	8717	75	.936	3014	102	.001	65263	139
.808	2808	56	.872	8642	75	.937	2912	102	.002	65124	139
.809	2752	56	.873	8566	76	.938	2810	102	.003	64984	140
.810	2696	56	.874	8491	75	.939	2707	103	.004	64844	140
.811	2639	57	.875	8415	76	.940	2604	103	.005	64703	141
.812	2582	57	.876	8338	77	.941	2500	104	.006	64561	142
.813	2525	57	.877	8261	77	.942	2395	105	.007	64419	142
.814	2468	57	.878	8183	78	.943	2290	105	.008	64276	143
.815	2410	58	.879	8106	77	.944	2185	105	.009	64133	143
.816	2352	58	.880	8028	78	.945	2079	106	.010	63989	144
.817	2294	58	.881	7949	79	.946	1973	106	.011	63844	145
.818	2235	59	.882	7871	78	.947	1866	107	.012	63698	146
.819	2177	58	.883	7792	79	.948	1758	108	.013	63552	146
.820	2118	59	.884	7713	79	.949	1650	108	.014	63405	147
.821	2059	59	.885	7633	80	.950	1541	109	.015	63257	148
.822	1999	60	.886	7553	80	.951	1432	109	.016	63108	149
.823	1940	59	.887	7472	81	.952	1322	110	.017	62959	149
.824	1880	60	.888	7391	81	.953	1212	110	.018	62809	150
.825	1820	60	.889	7309	82	.954	1101	111	.019	62658	151
.826	1759	61	.890	7226	83	.955	0991	110	.020	62507	151
.827	1698	61	.891	7144	82	.956	0879	112	.021	62355	152
.828	1636	62	.892	7061	83	.957	0767	112	.022	62202	153
.829	1575	61	.893	6978	83	.958	0654	113	.023	62048	154
.830	1513	62	.894	6895	83	.959	0541	113	.024	61894	154
.831	1451	62	.895	6811	84	.960	0427	114	.025	61739	155
.832	1388	63	.896	6727	84	.961	0313	114	.026	61583	156
.833	1326	62	.897	6643	84	.962	0198	115	.027	61426	157
.834	1263	63	.898	6558	85	.963	0083	115	.028	61269	157
.835	1200	63	.899	6472	86	.964	69967	116	.029	61111	158
.836	1137	63	.900	6387	85	.965	69850	117	.030	60953	158
.837	1073	64	.901	6301	86	.966	69733	117	.031	60794	159
.838	1009	64	.902	6215	86	.967	69615	118	.032	60634	160
.839	0944	65	.903	6127	88	.968	69497	118	.033	60473	161
.840	0880	64	.904	6040	87	.969	69378	119	.034	60311	162
.841	0815	65	.905	5952	88	.970	69259	119	.035	60148	163
.842	0749	66	.906	5863	89	.971	69139	120	.036	59984	164
.843	0684	65	.907	5775	88	.972	69019	120	.037	59820	164
.844	0618	66	.908	5686	89	.973	68898	121	.038	59655	165
.845	0552	66	.909	5597	89	.974	68777	121	.039	59489	166
8.846	0486	66	8.910	5507	90	8 975	68655	122	9.040	59322	167

TABLE IV.—(CONTINUED.)

log. $\frac{\tau''}{(r+r')^{\frac{3}{2}}}$	log. $\frac{3-q''}{3\sqrt{2}}$	Dif.	log. $\frac{\tau''}{(r+r')^{\frac{3}{2}}}$	log. $\frac{3-q''}{3\sqrt{2}}$	Dif.	log. $\frac{\tau''}{(r+r')^{\frac{3}{2}}}$	log. $\frac{3-q''}{3\sqrt{2}}$	Dif.	log. $\frac{\tau''}{(r+r')^{\frac{3}{2}}}$	log. $\frac{3-q''}{3\sqrt{2}}$	Dif.
	9.84			9.84			9.84			9.84	
9.040	59322		9.080	51954		9.120	43013		9.160	32135	
.041	59154	168	.081	51751	203	.121	42766	247	.161	31835	300
.042	58986	168	.082	51547	204	.122	42518	248	.162	31534	301
.043	58817	169	.083	51342	205	.123	42269	249	.163	31231	303
.044	58647	170	.084	51136	206	.124	42019	250	.164	30927	304
.045	58476	171	.085	50929	207	.125	41768	251	.165	30621	306
.046	58305	171	.086	50721	208	.126	41515	253	.166	30313	308
.047	58133	172	.087	50512	209	.127	41261	254	.167	30003	310
.048	57960	173	.088	50302	210	.128	41006	255	.168	29692	311
.049	57786	174	.089	50091	211	.129	40749	257	.169	29379	313
.050	57611	175	.090	49879	212	.130	40491	258	.170	29064	315
.051	57436	175	.091	49666	213	.131	40231	260	.171	28748	316
.052	57260	176	.092	49452	214	.132	39970	261	.172	28431	317
.053	57083	177	.093	49237	215	.133	39708	262	.173	28112	319
.054	56905	178	.094	49020	217	.134	39445	263	.174	27791	321
.055	56726	179	.095	48803	217	.135	39181	264	.175	27469	322
.056	56546	180	.096	48584	219	.136	38916	265	.176	27146	323
.057	56365	181	.097	48365	219	.137	38649	267	.177	26821	325
.058	56183	182	.098	48144	221	.138	38381	268	.178	26494	327
.059	56000	183	.099	47923	221	.139	38112	269	.179	26166	328
.060	55816	184	.100	47700	223	.140	37842	270	.180	25836	330
.061	55631	185	.101	47476	224	.141	37570	272	.181	25504	332
.062	55445	186	.102	47251	225	.142	37297	273	.182	25170	334
.063	55258	187	.103	47025	226	.143	37023	274	.183	24835	335
.064	55071	187	.104	46798	227	.144	36747	276	.184	24498	337
.065	54883	188	.105	46570	228	.145	36469	278	.185	24160	338
.066	54694	189	.106	46341	229	.146	36190	279	.186	23820	340
.067	54505	189	.107	46110	231	.147	35910	280	.187	23478	342
.068	54315	190	.108	45879	231	.148	35628	282	.188	23134	344
.069	54124	191	.109	45646	233	.149	35344	284	.189	22789	345
.070	53932	192	.110	45413	233	.150	35059	285	.190	22442	347
.071	53739	193	.111	45179	234	.151	34773	286	.191	22093	349
.072	53545	194	.112	44944	235	.152	34485	288	.192	21743	350
.073	53349	196	.113	44707	237	.153	34196	289	.193	21391	352
.074	53152	197	.114	44469	238	.154	33906	290	.194	21037	354
.075	52955	197	.115	44230	239	.155	33614	292	.195	20681	356
.076	52757	198	.116	43990	240	.156	33321	293	.196	20323	358
.077	52558	199	.117	43748	242	.157	33027	294	.197	19963	360
.078	52358	200	.118	43504	244	.158	32731	296	.198	19602	361
.079	52157	201	.119	43259	245	.159	32434	297	.199	19239	363
9.080	51954	203	9.120	43013	246	9 160	32135	299	9.200	18874	365

TABLE V.

log. $(1-q'')$	log. $\mathbf{y}''$	Dif.	log. $(1-q'')$	log. $\mathbf{y}''$	Dif.	log. $(1-q'')$	log. $\mathbf{y}''$	Dif.	log. $(1-q'')$	log. $\mathbf{y}''$	Dif.	log. $(1-q'')$	log. $\mathbf{y}''$	Dif.
	0.0			0.0			0.0			0.0			0.0	
0.000	000000		9.986	093832		9.972	188658		9.958	284464		9.944	381238	
9.999	006669	6669	.985	100573	6741	.971	195469	6811	.957	291345	6881	.943	388187	6949
.998	013343	6674	.984	107318	6745	.970	202285	6816	.956	298230	6885	.942	395141	6954
.997	020023	6680	.983	114069	6751	.969	209106	6821	.955	305120	6890	.941	412100	6959
.996	026708	6685	.982	120824	6755	.968	215932	6826	.954	312015	6895	.940	409065	6965
.995	033398	6690	.981	127585	6761	.967	222763	6831	.953	318915	6900	.939	416034	6969
.994	040093	6695	.980	134351	6766	.966	229599	6836	.952	325820	6905	.938	423008	6974
.993	046793	6700	.979	141122	6771	.965	236439	6840	.951	332730	6910	.937	429986	6978
.992	053498	6705	.978	147898	6776	.964	243284	6845	.950	339646	6916	.936	436969	6983
.991	060208	6710	.977	154679	6781	.963	250134	6850	.949	346566	6920	.935	443956	6987
.990	066922	6714	.976	161465	6786	.962	256990	6856	.948	353491	6925	.934	450949	6993
.989	073642	6720	.975	168255	6790	.961	263851	6861	.947	360421	6930	.933	457947	6998
.988	080367	6725	.974	175051	6796	.960	270717	6866	.946	367355	6934	.932	464950	7003
.987	087097	6730	.973	181852	6801	.959	277588	6871	945	374294	6939	.931	471957	7007
9.986	093832	6735	9.972	188658	6806	9.958	284464	6876	9.944	381238	6944	9.930	478969	7012

TABLE V.—(CONTINUED.)

log. $(1-q'')$	log. $\mathbf{y}''$	Dif.	log. $(1-q'')$	log. $\mathbf{y}''$	Dif.	log. $(1-q'')$	log. $\mathbf{y}''$	Dif.	log. $(1-q'')$	log. $\mathbf{y}''$	Dif.	log. $(1-q'')$	log $\mathbf{y}''$	Dif.
	0.0			0.0			0.1			0.1			0.2	
9.930	478969		9.865	944905		9.801	422326		9.736	924817		9.672	435572	
.929	485986	7017	.864	952226	7321	.800	429926	7600	.735	932679	7862	.671	443671	8099
.928	493008	7022	.863	959551	7325	.799	437530	7604	.734	940545	7866	.670	451774	8103
.927	580035	7027	.862	966881	7330	.798	445138	7608	.733	948415	7870	.669	459880	8106
.926	507067	7032	.861	974215	7334	.797	452750	7612	.732	956289	7874	.668	467990	8110
.925	514104	7037	.860	981554	7339	.796	460366	7616	.731	964166	7877	.667	476103	8113
.924	521145	7041	.859	988897	7343	.795	467987	7621	.730	972047	7881	.666	484220	8117
.923	528191	7046	.858	906244	7347	.794	475612	7625	.729	979932	7885	.665	492340	8120
.922	535242	7051		0 1		.793	483241	7629	.728	987821	7889	.664	500463	8123
.921	542298	7056	.857	003596	7352	.792	490874	7633	.727	995714	7893	.663	508590	8127
.920	549358	7060	.856	010953	7357	.791	498511	7637		0.2		.662	516721	8131
.919	556423	7065	.855	018315	7362	.790	506153	7642	.726	003610	7896	.661	524856	8135
.918	563493	7070	.854	025681	7366	789	513799	7646	.725	011510	7900	.660	532994	8138
.917	570568	7075	.853	033051	7370	788	521449	7650	.724	019414	7904	.659	541136	8142
.916	577647	7079	.852	040425	7374	.787	529103	7654	.723	027322	7908	.658	549281	8145
.915	584731	7084	.851	047804	7379	.786	536761	7658	.722	035234	7912	.657	557429	8148
.914	591820	7089	.850	055187	7383	.785	544422	7661	.721	043150	7916	.656	565581	8152
.913	598914	7094	.849	062575	7388	.784	552088	7666	.720	051070	7920	.655	573736	8155
.912	606012	7098	.848	069967	7392	.783	559758	7670	.719	058993	7923	.654	581895	8159
.911	613115	7103	.847	077364	7397	.782	567432	7674	.718	066920	7927	.653	590057	8162
.910	620223	7108	.846	084765	7401	.781	575111	7679	.717	074851	7931	.652	598223	8166
.909	627336	7113	.845	092171	7406	.780	582794	7683	.716	082786	7935	.651	606392	8169
.908	634454	7118	.844	099581	7410	.779	590481	7687	.715	090725	7939	.650	614565	8173
.907	641576	7122	.843	106995	7414	.778	598172	7691	.714	098667	7942	.649	622741	8176
.906	648703	7127	.842	114414	7419	.777	605867	7695	.713	106613	7946	.648	630921	8180
.905	655834	7134	.841	121837	7423	.776	613566	7699	.712	114563	7950	.647	639104	8183
.904	662970	7136	.840	129265	7428	.775	621269	7703	.711	122516	7953	.646	647290	8186
.903	670111	7141	.839	136697	7432	.774	628976	7707	.710	130473	7957	.645	655480	8190
.902	677257	7146	.838	144133	7436	.773	636687	7711	.709	138434	7961	.644	663673	8193
.901	684407	7150	.837	151574	7441	.772	644402	7715	.708	146399	7965	.643	671869	8196
.900	691562	7155	.836	159019	7445	.771	652122	7720	.707	154367	7968	.642	680069	8200
.899	698722	7160	.835	166469	7450	.770	659846	7724	.706	162339	7972	.641	688272	8203
.898	705886	7164	.834	173923	7454	.769	667574	7728	.705	170315	7976	.640	696479	8207
.897	713055	7169	.833	181382	7459	.768	675306	7732	.704	178295	7980	.639	704689	8210
.896	720229	7174	.832	188845	7463	.767	683041	7735	.703	186278	7983	.638	712903	8214
.895	727407	7178	.831	196312	7467	.766	690780	7739	.702	194265	7987	.637	721120	8217
.894	734590	7183	.830	203783	7471	.765	698523	7743	.701	202256	7991	.636	729340	8220
.893	741778	7188	.829	211259	7476	.764	706270	7747	.700	210250	7994	.635	737564	8224
.892	748970	7192	.828	218739	7480	.763	714022	7752	.699	218248	7998	.634	745791	8227
.891	756167	7197	.827	226223	7484	.762	721778	7756	.698	226250	8002	.633	754022	8231
.890	763369	7202	.826	233712	7489	.761	729538	7760	.697	234255	8005	.632	762256	8234
.889	770575	7206	.825	241205	7493	.760	737302	7764	.696	242264	8009	.631	770493	8237
.888	777786	7211	.824	248702	7497	759	745070	7768	.695	250277	8013	.630	778733	8240
.887	785002	7216	.823	256204	7502	758	752842	7772	.694	258294	8017	.629	786977	8244
.886	792222	7220	.822	263710	7506	.757	760618	7776	.693	266314	8020	.628	795224	8247
.885	799447	7225	.821	271220	7510	.756	768397	7779	.692	274338	8024	.627	803474	8250
.884	806676	7229	.820	278735	7515	.755	776180	7783	.691	282365	8027	.626	811728	8254
.883	813910	7234	.819	286254	7519	.754	783967	7787	.690	290395	8030	.625	819985	8257
.882	821149	7239	.818	293777	7523	.753	791758	7791	.689	298429	8034	.624	828245	8260
.881	828392	7243	.817	301305	7528	.752	799554	7796	.688	306467	8038	.623	836509	8264
.880	835640	7248	.816	308837	7532	.751	807354	7800	.687	314509	8042	.622	844776	8267
.879	842892	7252	.815	316373	7536	.750	815158	7804	.686	322555	8046	621	853046	8270
.878	850149	7257	.814	323913	7540	.749	822966	7808	.685	330604	8049	.620	861319	8273
877	857411	7262	.813	331458	7545	.748	830778	7812	.684	338657	8053	.619	869596	8277
.876	864677	7266	.812	339007	7549	.747	838593	7815	.683	346714	8057	.618	877876	8280
.875	871948	7271	.811	346561	7554	.746	846412	7819	.682	354774	8060	.617	886159	8283
.874	879223	7275	.810	354119	7558	.745	854234	7822	.681	362837	8063	.616	894446	8287
.873	886503	7280	.809	361681	7562	744	862061	7827	.680	370904	8067	.615	902736	8290
.872	893787	7284	.808	369247	7566	743	869892	7831	.679	378975	8071	.614	911029	8293
.871	901076	7289	.807	376817	7570	.742	877727	7835	.678	387049	8074	.613	919325	8296
.870	908370	7294	.806	384391	7574	.741	885565	7838	.677	395127	8078	.612	927625	8300
.869	915668	7298	.805	391970	7579	740	893407	7842	.676	403209	8082	.611	935928	8303
.868	922971	7303	.804	399553	7583	.739	901254	7847	.675	411295	8086	.610	944234	8306
.867	930278	7307	.803	407140	7587	.738	909104	7850	.674	419384	8089	.609	952543	8309
.866	937589	7311	.802	414731	7591	.737	916959	7855	.673	427476	8092	.608	960856	8313
9 865	944905	7316	9.801	422326	7595	9.736	924817	7858	9.672	435572	8096	9.607	969172	8316

TABLE V.—(CONTINUED.)

log. $(1-q'')$	log. y''	Dif.	log. $(1-q'')$	log. y''	Dif.	log. $(1-q'')$	log. y''	Dif.	log. $(1-q'')$	log. y''	Dif.	log. $(1-q'')$	log. y''	Dif.
	0 2			0 3			0.3			0.3			0.3	
9.607	969172		9.586	144542		9.564	329739		9.542	516393		9.521	[illegible]	
.606	977491	8319	.585	152928	8386	.563	338192	8453	.541	524911	8518	.520	704454	8578
.605	985813	8322	.584	161317	8389	.562	346648	8456	.540	533431	8520	.519	713034	8580
.604	994138	8325	.583	169709	8392	.561	355107	8459	.539	541955	8524	.518	721618	8584
	0 3		.582	178104	8395	.560	363568	8461	.538	550481	8526	.517	730204	8586
.603	002467	8329	.581	186502	8398	.559	372033	8465	.537	559011	8530	.516	738794	8590
.602	010799	8332	.580	194903	8401	.558	380501	8468	.536	567544	8533	.515	747386	8592
.601	019134	8335	.579	203307	8404	.557	388972	8471	.535	576080	8536	.514	755981	8595
.600	027473	8339	.578	211714	8407	.556	397446	8474	.534	584619	8539	.513	764579	8598
.599	035814	8341	.577	220124	8410	.555	405923	8477	.533	593161	8542	.512	773180	8601
.598	044158	8344	.576	228538	8414	.554	414403	8480	.532	601705	8544	.511	781783	8603
.597	052506	8348	.575	236955	8417	.553	422886	8483	.531	610252	8547	.510	790389	8606
.596	060857	8351	.574	245375	8420	.552	431372	8486	.530	618801	8549	.509	798998	8609
.595	069212	8355	.573	253798	8423	.551	439861	8489	.529	627353	8552	.508	807610	8612
.594	077570	8358	.572	262224	8426	.550	448352	8491	.528	635908	8555	.507	816224	8614
.593	085931	8361	.571	270652	8428	.549	456846	8494	.527	644466	8558	.506	824841	8617
.592	094295	8364	.570	279084	8432	.548	465343	8497	.526	653027	8561	.505	833460	8619
.591	102662	8367	.569	287519	8435	.547	473844	8501	.525	661592	8565	.504	842082	8622
.590	111031	8369	.568	295957	8438	.546	482348	8504	.524	670159	8567	.503	850707	8625
.589	119404	8373	.567	304398	8441	.545	490855	8507	.523	678729	8570	.502	859335	8628
.588	127780	8376	.566	312842	8444	.544	499365	8510	.522	687301	8572	.501	867966	8631
.587	136159	8379	.565	321289	8447	.543	507878	8513	9.521	695876	8575	9.500	876600	8634
9.586	144542	8383	9.564	329739	8450	9.542	516393	8515						

TABLE VI.

Correction of the Sun's Apparent Longitude to reduce it to the Mean Equinox for the Beginning of the Year.

	B. 1848.	1849.	1850.	1851.	B. 1852.	1853.	1854.	1855.	B. 1856.	1857.	1858.	1859.	log. $\frac{\sin. 1''}{k} R^2$
Jan. 1,	+18″.8	+24″.6	+29″.9	+34″.1	+36″.8	+37″.6	+36″.4	+33″.4	+29″.0	+23″.5	+17″.7	+12″.2	6.435
11,	17.2	23.0	28.3	32.5	35.1	35.8	34.6	31.6	27.1	21.6	15.8	10.3	.435
21,	15.7	21.5	26.8	30.9	33.5	34.2	32.9	29.8	25.3	19.8	14.0	8.5	.436
31,	14.3	20.1	25.3	29.5	32.0	32.6	31.3	28.2	23.6	18.1	12.3	6.8	.437
Feb. 10,	13.1	18.9	24.1	28.2	30.6	31.2	29.8	26.7	22.1	16.6	10.8	5.3	.438
20,	12.0	17.8	23.0	27.0	29.4	30.0	28.5	25.3	20.7	15.1	9.3	3.9	.440
March 2,	11.1	16.9	22.0	26.0	28.4	28.8	27.3	24.1	19.4	13.9	8.1	2.7	.443
12,	10.2	16.0	21.1	25.1	27.4	27.8	26.3	23.0	18.3	12.7	6.9	1.5	.445
22,	9.4	15.1	20.3	24.2	26.4	26.8	25.2	21.9	17.1	11.6	5.8	+ 0.4	.448
April 1,	8.5	14.3	19.3	23.2	25.4	25.7	24.1	20.7	15.9	10.3	4.5	— 0.8	.450
11,	7.6	13.3	18.4	22.2	24.4	24.6	23.0	19.5	14.7	9.1	3.3	2.0	.452
21,	6.6	12.3	17.4	21.1	23.2	23.4	21.7	18.2	13.4	7.8	2.0	3.3	.455
May 1,	5.4	11.1	16.2	19.9	22.0	22.1	20.3	16.8	12.0	6.3	+ 0.5	4.8	.457
11,	4.2	9.9	14.9	18.6	20.6	20.7	18.9	15.3	10.4	4.8	— 1.0	6.3	.459
21,	2.8	8.5	13.4	17.1	19.0	19.1	17.2	13.6	8.7	3.0	2.8	8.0	.460
31,	+ 1.2	6.9	11.8	15.5	17.4	17.4	15.4	11.8	6.8	+ 1.2	4.6	9.8	.462
June 10,	— 0.4	5.3	10.2	13.8	15.6	15.6	13.6	9.9	4.9	— 0.7	6.5	11.7	.463
20,	2.0	3.6	8.5	12.0	13.8	13.7	11.7	8.0	3.0	2.7	8.5	13.7	.464
30,	3.6	2.0	6.9	10.4	12.1	12.0	9.9	6.1	+ 1.1	4.6	10.4	15.5	.464
July 10,	5.2	+ 0.5	5.3	8.7	10.4	10.2	8.1	4.2	— 0.8	6.5	12.3	17.4	.464
20,	6.7	— 1.1	3.7	7.1	8.8	8.5	6.3	2.5	2.6	8.3	14.1	19.2	.463
30,	8.1	2.5	2.3	5.6	7.2	6.9	4.7	+ 0.8	4.3	10.0	15.8	20.8	.463
Aug. 9,	9.3	3.7	+ 1.0	4.3	5.9	5.5	3.2	— 0.7	5.8	11.5	17.3	22.3	.462
19,	10.3	4.8	— 0.1	3.2	4.7	4.2	1.9	2.1	7.2	13.0	18.7	23.7	.460
29,	11.3	5.7	1.1	2.1	3.6	3.1	+ 0.7	3.3	8.5	14.2	19.9	24.9	.458
Sept. 8,	12.1	6.6	2.0	1.2	2.6	2.1	— 0.4	4.4	9.6	15.4	21.0	26.0	.456
18,	12.9	7.3	2.8	+ 0.4	1.7	1.1	1.4	5.5	10.7	16.5	22.1	27.0	.454
28,	13.6	8.1	3.6	— 0.4	+ 0.8	+ 0.2	2.4	6.5	11.7	17.5	23.2	28.1	.451
Oct. 8,	14.4	8.9	4.4	1.3	— 0.1	— 0.8	3.4	7.5	12.8	18.6	24.2	29.1	.449
18,	15.2	9.7	5.3	2.3	1.1	1.8	4.5	8.7	13.9	19.8	25.4	30.2	.446
28,	16.2	10.7	6.3	3.3	2.2	3.0	5.7	9.9	15.2	21.0	26.7	31.5	.444
Nov. 7,	17.3	11.8	7.4	4.5	3.4	4.3	7.0	11.3	16.6	22.4	28.0	32.8	.442
17,	18.5	13.1	8.7	5.9	4.8	5.7	8.5	12.8	18.2	24.0	29.6	34.3	.440
27,	19.9	14.5	10.2	7.4	6.4	7.4	10.2	14.5	19.9	25.6	31.3	36.0	.438
Dec. 7,	21.5	16.1	11.8	9.0	8.1	9.1	12.0	16.3	21.7	27.6	33.1	37.8	.437
17,	23.1	17.7	13.5	10.7	9.9	11.0	13.9	18.3	23.7	29.5	35.0	39.7	.436
27,	—24.7	—19.4	—15.2	—12.5	—11.7	—12.8	—15.7	—20.2	—25.6	—31.5	—37.0	—41.6	6.435

The last column contains the logarithms of the decimal of a day required by the Sun to describe one second in longitude.

VII.

An Attempt to discriminate and describe the Animals that made the Fossil Footmarks of the United States, and especially of New England.

By EDWARD HITCHCOCK, D. D., LL. D.,

PRESIDENT OF AMHERST COLLEGE, AND PROFESSOR OF NATURAL THEOLOGY AND GEOLOGY.

(*Communicated to the Academy, April 29th,* 1848.)

It is now about thirteen years since my attention was called to the fossil footmarks of New England; and every successive year has brought out some new developments of this curious subject. At first, even by most scientific men, it was regarded with extreme skepticism, and by others with ridicule. But facts, registered imperishably on tables of stone, have now, for the most part, given conviction to men of real science, and turned into admiration the scoffs of the superficial. It is now generally admitted, that the opening of these stony leaves of the earth's volume, with their deeply impressed hieroglyphics, has revealed a new chapter of preadamic history, which all are anxious to peruse. Fully to decipher it is no easy, although a fascinating, task. Thirteen years, however, have witnessed some progress in the work; and my object at this time is to present the most mature results that have been reached.

I have already, in other places, given such details respecting

the earliest discovery of fossil footmarks, that I shall omit them here; especially as my object is to give my latest, rather than my early, views of the subject. I shall, therefore, only mention the successive developments which my views have undergone.

The footmarks hitherto discovered in the United States out of New England amount to two or three species only; and although I shall describe these in the present paper, yet all the important characters on which I found my results are derived from those of the valley of Connecticut River.

The first account ever published of these footmarks was given in the *American Journal of Science* for 1836, where I figured and described seven species; that is, I supposed that these tracks were made by seven different species of animals. And since I had no evidence that all of them were not bipeds, and positive evidence that most of them were, I named the tracks *Ornithichnites;* but left the animals themselves unnamed. Five years of further examination enabled me to swell this list to twenty-seven species; of which I gave a description, with drawings of the natural size, in 1841, in my *Final Report on the Geology of Massachusetts.* Up to that time, however, I had no sure evidence that any of them were made by quadrupeds. Yet a large proportion of them bore such a strong resemblance to the tracks of saurian reptiles, that I denominated them *Sauroidichnites;* intending, however, by the term, merely to convey an intimation that they might prove to be reptilian. To the other tracks I applied the name of *Ornithoidichnites.* In 1841, when, in the Transactions of the Association of American Geologists, I gave an account of five more species of tracks, I first ventured to describe one species as of decidedly quadrupedal origin, namely, the *Sauroidichnites Deweyi.* In my Report on Ichnolithology, made to the Association of American

Geologists and Naturalists at Washington, in 1844, and published in the forty-seventh volume of the *American Journal of Science*, I described four other species of tracks; and in the same work for July, 1847, Vol. IV., New Series, I added two additional species. Several other new species have remained in my possession undescribed, from the pressure of more important duties. My present memoir will embrace *forty-nine species*, not simply of footmarks, but of the animals that made them, so far as their characters can be ascertained. Of these, twelve were certainly quadrupeds, four of them probably lizards, two chelonians, and six batrachians; two were annelids, or molluscs; three are of doubtful character; and the remaining thirty-two species were bipeds, so far as our present information extends. Eight of them seem to have been thick-toed tridactylous birds; fourteen others were probably narrow-toed tridactylous or tetradactylous birds; two were perhaps bipedal batrachians; and the remaining eight may have been birds, but will more probably turn out to have been either lizards or batrachians. Of these forty-nine species, forty-seven occur in the valley of Connecticut River, in Massachusetts and Connecticut.

I have little doubt that many will at once pronounce it impossible that the tracks of so large a number of animals should be distinguished in a few quarries in that valley. I shall shortly present the characteristics of each particular track, from which the comparative anatomist and zoölogist can judge whether I have multiplied the species too much. But there are a few general considerations, which may take away all antecedent improbability as to the existence and discovery of so large a number.

And, first, we have now found these tracks in at least twenty-one places, scattered through an extent of nearly eighty miles; that is, from the Horse Race, three miles above Turner's Falls in Gill,

to Middletown in Connecticut. These localities occur at the Horse Race in Gill; near the ferry at Turner's Falls, on the Gill shore; below the falls, on the same shore; at the dam on the Montague shore, at the same falls; a mile and a half south of this spot, in Montague, on the road from Greenfield to Athol, on the east side of the canal; between the bridges over Connecticut and Deerfield rivers; at a quarry in the southeast part of Montague; near Pliny Moody's house in the north part of South Hadley; a mile west from this spot; on the west face of Mount Holyoke, beneath the trap, at Titan's Piazza; on the west bank of Connecticut river, at the east foot of Mount Tom, in Northampton; at South Hadley canal; at Cabotville; one mile south of Cabotville, on the road to Springfield; at Chicopee Falls; at a quarry on the west bank of Connecticut river, in Suffield, near the Enfield bridge; at Rocky Hill in Hartford; at the cove in Wethersfield; and at a spot one or two miles further south; at the Chatham quarries; and two or three miles west of Middletown. At so many localities, so widely scattered through the valley, we might expect to find the tracks of all the important species of animals that frequent the shores of an estuary.

This will be still more obvious, secondly, when we consider the position of the rocks at many of these localities. Ridges of trap-rock run nearly north and south through the whole extent of the sandstone, and by their protrusion they have lifted up the strata on the east side, while they overlie the sandstone on the west side. Now, in every instance but one, it is on the east or upper side of the trap that the tracks occur; and since the sandstone strata there are often tilted up from 20° to 50°, we have an opportunity of examining the edges of successive deposits made during a great length of time. Often the successive layers lie

open several rods in thickness, and sometimes, as at Turner's Falls, more than a quarter of a mile; and thus we can easily learn what animals trod upon the deposits through a series of thousands of years: for we can hardly suppose, that, in such fine sediment as that which composes these rocks, the accumulations could have been more than an inch or two each year.

Consider, thirdly, that we usually find the tracks limited to a belt of rock only a few feet wide, which formed the shore of the ancient estuary. Along this pathway, we should naturally expect to find the tracks of all the animals that trod those ancient shores.

Suppose, now, that only as many animals of this kind formerly lived in this valley as now do, — and since the climate was then tropical, and that was the period when the batrachian, lacertilian, and chelonian races were greatly developed (to say nothing of Struthionidæ), this cannot be regarded as an extravagant supposition, — might we not expect to find, at so many localities, and on so many hundred successive layers of rock, as many as forty-seven species of animals capable of being distinguished by their tracks? for we do not suppose that all species can be thus distinguished. However, it would be strange if I should not have sometimes been mistaken as to species, where they must be described only from their tracks, and, in consequence of imperfect specimens, have made two species out of one. After I have described the whole, naturalists can better judge on this point; and my only wish is to have all species dropped that have not good distinctive characters. The species which I regard as the most uncertain are the Brontozoum expansum, Steropezoum elegantius, Argozoum Redfieldianum and mininum, Platypterna Deaniana, Ornithopus Adamsonus, Plectropus minitans, Triænopus Emmonsianus, Anisopus gracilis, and the three species of Harpagopus. If all these should turn

out to be varieties of other species, it would reduce the number to thirty-eight species; thirty-six of which are found in New England.

Hitherto I have spoken of names given to the tracks. But two or three years ago, my friend, James D. Dana, Esq., suggested the desirableness of applying names to the animals that made the tracks. Accordingly, at the meeting of the Association of American Geologists and Naturalists in New Haven, in 1845, I presented a catalogue of all the animals then known through their tracks, which was printed in the abstract of the proceedings of that meeting. But as the names were not accompanied by drawings or descriptions, they would not be allowed as authoritative by the rules adopted among naturalists; and therefore, in this paper, I have made several alterations, as well as additions, and have given full descriptions, as well as outline sketches. And in regard to the latter I would add, that, for the discrimination of species, they are better than full-shaded drawings of individual specimens, because they present more distinctly the essential characters. My outline drawings, moreover, it should be remarked, are not always derived from a single specimen. For when a particular part on one specimen was defective, I have copied that part from other specimens which exhibited it more fully. So that, in fact, the outline tracks which accompany this paper are, in most cases, *restored tracks;* and yet, in general, they are copied from single, very perfect specimens. In no case is any part supplied by imagination; and hence, in a few instances, I have been obliged to omit some parts of the track.

My mode of obtaining these outlines, almost without exception, has been, first to trace them exactly upon plates of mica, laid over the tracks, several pieces when necessary being fastened togeth-

er, and afterwards to copy them on thin paper placed over the mica. When reduced subsequently, the proportions were accurately preserved.

I ought here, however, to consider an opinion, which I have met occasionally, and which goes against the whole system of giving scientific names to fossil tracks, or to the animals that made them. It is considered a useless show of learning, because it is supposed that the data afforded by tracks alone are not definite and full enough to discriminate species, which can be done only by the discovery of their skeletons.

I take a different view of this subject, and maintain, that, by the principles of fossil zoölogy, we are fully justified in classifying and naming animals from the evidence of their tracks alone ; and in support of this opinion, I offer the following reasons.

In the first place, no naturalist who has seen a good suite of these fossil footmarks will doubt that they prove the existence of certain animals during the deposition of the new red sandstone of the Connecticut valley. Many are skeptical on the subject till they have actually seen good specimens ; but a glance of the eye usually carries the conviction to the mind, that the tracks were made by animals, almost as certainly as if their skeletons were standing before the observer.

In the second place, these extinct animals have never been described. Very few vertebral animals have been found in the new red sandstone of any country, and none in that rock in our country, save fishes. Those which have left only their tracks, therefore, deserve names as much as any other animals, living or fossil, if we can find out what are their characters.

In the third place, every one who examines these tracks admits at once that they were made by several distinct species of animals.

He sees that some of them were impressed by bipeds, others by quadrupeds; some by thick-toed animals, and others by narrow-toed; some by three-toed, others by four-toed, and others by five-toed animals; some by long and narrow heeled, others by short and broad heeled, and others by *heelless* animals. Nor can he, by any effort of the imagination, conceive how they all were made by a single animal. I never knew a man who attempted to do this. Let any one examine the outline drawings accompanying this paper, and he will be satisfied on this point. Now there must be some very decided characters in these tracks, that produce this conviction of differences in the animals that made them. And why may not these peculiarities be expressed on paper, and thus in fact become the basis of generic and specific characters? True, they are imperfect; but so are the characters of a large part of the genera and species of fossil animals and plants.

In the fourth place, the feet of animals furnish excellent characters for distinguishing classes, orders, genera, and species. To be satisfied of this point, let any one compare the feet of mammiferous animals with those of reptiles; or the latter with those of birds; or among the Mammalia, the feet of the Ruminantia with those of the Carnivora, or Marsupialia; or, among birds, the feet of the Grallæ with those of the Passeres, or Palmipedes; or the feet of the kangaroo, or Platypus, with those of the tiger or hog; or those of the Struthio Rhea with those of the eagle, or albatross, or jacana. Indeed, the characters of several of the orders of birds are drawn from their feet. Many other animals could, to a considerable extent, be classified on the same basis. When we attempt in the same way to distinguish genera and species, we are met by too many exceptions to make such characters an easy and safe guide. But in the absence of better distinctions, they might be used with

tolerable success; so true is the correlation between different parts of animals. Hitherto, as I shall endeavour to show in this paper, only a small part of the characters that have a permanent value in distinguishing the feet have been pointed out, merely because they are not needed for living animals. Nevertheless, where only a mould or cast of the foot remains, they may be of great service.

I might add, in this connection, that the classes of animals which seem to have made the fossil footmarks are of all others most easily distinguished by their feet; I mean reptiles and birds. The chief difficulty in the case lies in the fact, that, in the red-sandstone period, some of these animals seem to have differed not a little in their structure from the tribes now living. The sure laws of comparative anatomy, however, are not violated.

In the fifth place, many fossil animals have been described from characters no more numerous, or definite, than those derived from their feet alone. A single bone or the fragment of a bone is, indeed, sometimes alone sufficient to enable the comparative anatomist to construct the whole animal. But it is not every bone that will do this; and as to plants, it is still more difficult to make out their true place in the botanical scale from single parts. And we know that, in many instances, animals have been named and described which were subsequently found to have been referred even to the wrong class; as, for example, the Pterodactyle and Zeuglodon. Indeed, the possession of an entire skeleton is not always sufficient to distinguish the species, nor even the genus (*Ossemens Fossiles*, Tom. III. p. 524, 3d ed.). Fossilization usually obscures the characters of organic beings; and every possible degree of uncertainty may be found in the catalogues of fossil animals. Yet in all cases, except the one under consideration, the principle seems to have been acted on, to give a name to an unknown animal, exhum-

ed from the rocks, according to all the light that can be obtained. If the zoölogist can only be satisfied that the animal once existed, and has not already been described, he feels justified in fixing upon it a name, which shall serve, at least, till a better one can be obtained. Why, then, should not the same principles guide us in respect to the beings that produced the fossil footmarks? Even if we admit that there is more uncertainty in our conclusions than in any case where a portion of the animal is preserved, (which, I fancy, no one who studies ichnolithology will maintain,) I do not see that the principle by which names are given is different.

Baron Cuvier has finely described the definiteness and certainty with which we can infer the character of an animal from its track, although when he wrote fossil footmarks were unknown. "Any one," says he, "who observes merely the print of a cloven hoof, may conclude that it has been left by a ruminant animal, and regard the conclusion as equally certain with any other in physics or morals. Consequently, this single footmark clearly indicates to the observer the forms of the teeth, of all the leg-bones, thighs, shoulders, and of the trunk of the body of the animal which left the mark. It is much surer than all the marks of Zadig."

In the sixth place, we have the highest authority for applying names to animals whose tracks are the only evidence of their existence.

This was done by Professor Kaup in the case of the Chirotherium. True, Professor Owen has subsequently given the name of Labyrinthidon to a batrachian whose bones he has examined, and which he conjectures to have been identical with the Chirotherium. But if I understand the rules of priority in regard to names adopted by naturalists, if no doubt exists as to the identity of the

Chirotherium and Labyrinthidon, the former name must be retained, and the latter dropped, and Professor Owen's right to apply another name depends solely on the doubt of their identity. And should that identity be hereafter made out, I do not see why his name ought not to be superseded by that of Professor Kaup. At any rate, I have never seen any intimation from the naturalists of Europe, that the latter had not good grounds for giving a name to a track-discovered animal.

A second example may be derived from Professor Owen. In his Report on British Reptiles, he gives the name *Testudo Duncani* to the animal that made the tracks on the new red sandstone of Scotland, which were described by Dr. Duncan in 1828. And in doing this, who can show, — who in Europe has attempted to show, — that Mr. Owen has not strictly conformed to the rules of zoölogical nomenclature?

Finally, convenience in description imperiously demands the application of names to these vanished animals of a former world, who have left only their footmarks behind. The naturalist cannot intelligibly describe the different sorts of these tracks, without giving to them distinctive characters; and unless he regards them all as varieties of one species, — which no scientific man will do, — how can he speak of them without the most inconvenient circumlocution, if he affixes no names either to the tracks or to the animals? Until he do this, he will find himself in inextricable embarrassment.

Upon the whole, I am led to the conclusion, that, in attempting to devise and affix names to the animals that made our fossil footmarks, if not to the tracks themselves, I am conforming to the strictest scientific principles. I may fail in drawing out their distinctive characters correctly; I may mistake varieties for species,

or confound different species together. But to such mistakes he who describes living, or other fossil animals, is always liable; and it cannot be an unpardonable offence, where the difficulty of correct discrimination is so much greater. I desire to have my names and distinctive characters judged of by the strictest rules of zoölogy and comparative anatomy; and if I am not right, let others make me so.

I beg leave to state here, however, that I do not base the names which I propose upon a supposed knowledge of the true place of the animals in the zoölogical scale; but rather upon some peculiarity of the feet, or supposed resemblance to known objects. So that should the animals be shown by subsequent discoveries to be very different from what I suppose them, still their generic and specific names will be equally unobjectionable.

The way is now prepared for enumerating and describing those characters, derived almost wholly from their footmarks, by which I propose to discriminate the lost animals that once trod the shores of this country, and particularly of that ancient estuary which extended from Long Island Sound across Connecticut and Massachusetts.

1. *Distinction between the thick-toed, or pachydactylous, and the narrow-toed, or leptodactylous, tracks.* — This distinction is very striking. The former show moulds or casts of toes, of great width, with distinct claws and protuberances, corresponding, probably, to the phalanges. The latter class, with a few exceptions belonging to intermediate species, probably, show very narrow toes, in which neither claws nor phalangeal protuberances can be distinguished. Sometimes the toes are very narrow, appearing almost as if the mud had been impressed by the blade of a knife; certainly by a toe not thicker than those of some delicate species of lizards.

It has been thought by some, that the difference between these two sorts of tracks was the result, not of a difference in the feet of the animals, but of the state of the mud impressed by them; that is, in the case of the narrow-toed tracks, the mud is supposed to have slid back so as to narrow the impression. That the mud did thus more or less collapse, in some cases, is evident. But it will not, in my opinion, explain the broad difference between these two sorts of tracks; and for the following reasons.

This supposition regards all the tracks as made by thick-toed animals. If so, only the mud near the surface would slide back and bring the margins of the impressions near together; and where that impression extends some inches in depth, as it does sometimes, the inferior layers of the narrow-toed tracks ought to be broader; but this is never the case to any great extent. As the track is at the surface (in respect to the width of the toes), so it is on all the layers. Secondly, no sliding back of the mud, after a thick-toed animal trod upon it, would obliterate the distinct phalangeal protuberances, without distorting the track in other respects. Thirdly, both sorts of tracks are not unfrequently found upon the same layer of rock, as at Wethersfield, Northampton, and Gill; and each exhibits its peculiar characteristics. Fourthly, the feet of living animals exhibit similar differences. Compare, for instance, the feet of the Struthionidæ with those of the Ardea, or Charadrius; or those of the thick-toed frogs with those of the Iguana, &c. Why, then, should we not look for diversities equally great among the fossil animals?

This character is a very important one in the classification of these animals. The group which I have denominated Struthionidæ is beautifully distinguished from all others in this way; they being all pachydactylous. For a long time I had supposed

that no others were so; but some of the quadrupeds, it appears, are almost equally entitled to this name, and the recently discovered Otozoum is eminently pachydactylous, although probably a batrachian.

2. *Winged feet.* — Two species of the pachydactylous animals appear to me to have been wing-footed, like the American coot and the grebe; for the membrane seems to have extended to the tip of the claw, as in the grebe. Their tracks are quite shallow, and the toes of great width, as distinctly lobate as those of the coot. The margin of the track appears as if a membrane had made a slight impression; but the whole depression has not that rounded form which is exhibited in the other pachydactylous tracks. Hence I have separated two species into a distinct genus on this ground. And yet it is possible to conceive such to have been the semifluid state of the mud when the track was made that the bottom of the depression beneath the animal's foot filled up in part, and the margin also partially slid inwards. Yet in such case the claw, it seems to me, would be scarcely affected at all; whereas, in fact, the peculiarity above described is most striking in that part of the track; and at present I incline to the opinion, that this character is to be relied upon for a generic distinction.

3. *Number of toes.* — This would seem at first view to be one of the best of characters; since in living animals the number of toes is rather constant in different classes of animals. But it requires a good deal of care not to be deceived in respect to the actual number of toes in the fossil footmarks. In living animals, especially birds, the hind toe is usually articulated to the tarso-metatarsus above its extremity, so that it often does not reach the ground, or only its extremity does so. And in the fossil footmarks we sometimes find that only the extreme point made an impression; and

that, too, only upon the uppermost layer. While the other toes seem to have depressed the layers of mud an inch or two, or more, in depth, this one reaches only a slight distance downward. Hence we often obtain specimens, apparently very perfect, in which the hind toe is wanting, when in fact it was present on a higher layer. The same liability to deception occurs in some cases when a short toe was attached to some part of a long heel, as it is in some reptiles. It might be only very rarely that it made an impression, save perhaps upon the highest layer.

The changes that take place in tracks in a vertical direction, that is, on successive layers of rock, is one of the most fruitful sources of error as to their true character and the number of toes. I have specimens which show the same track, or parts of it, to the depth of four or five inches; and if such a rock be split in different places, it will often show considerable diversity of forms, and yet it may be that all of them shall be quite distinct; so that, if we have only one layer, it is very difficult often to determine whether it was the identical layer on which the animal trod, or one above or below it. In following a track downward, the hind toe, if it had one, usually first disappears; next the heel, then the lateral toes, while the central one sinks the deepest.

In the plates annexed, I have given several examples of the changes that occur in tracks in a vertical direction, as they are shown upon successive layers of the rock. These, however, I ought to remark, are rather extreme cases. Plate 15, figs. 10–13, exhibits a track of *Triænopus Baileyanus* on four successive layers, the whole about two inches in thickness, fig. 10 being the uppermost layer. The dotted lines around the heel will be described in a subsequent part of this paper. Figs. 14–16 of the same plate show the *Triænopus Emmonsianus* on successive layers, but little more than

an inch in thickness. In this case, the three toes, near their roots, produce the appearance of a heel on the inferior layers; probably because, being so near together, all the mud between them was depressed together. Figs. 17–19 of the same plate exhibit a track of the hind and fore foot of *Plectropus longipes*, so united as to seem to be only one track. Nor is there any evidence, from this specimen, of two tracks having been made almost in the same spot. But the specimen of the same species, very analogous to this, shown on Plate 10, figs. 1–3, as seen on different layers, makes it almost certain that they are tracks of the hind and fore foot in both instances. The more detailed account of these specimens will be reserved until I come to describe the Plectropus longipes.

The above statements show us the great difficulty, in some cases, of ascertaining the precise layer of rock on which the animal walked. Where the surface was considerably firm, and quite different materials were drifted in afterwards, this question is not difficult to decide; for then the impression extends very little distance up or down, and is quite imperfect, save on one layer, which of course will be regarded as the one originally trodden upon. And fortunately such is the case with the larger proportion of tracks. But where the materials were very soft, it would seem as if the toes sank considerably into the mud, and were withdrawn without much disturbance; though afterwards the edges of the impression thus made approached each other. In no other way can we explain the extreme narrowness of some of the tracks found on the fine red shale, of Wethersfield especially. There, as already remarked, the impressions sometimes extend through from one to four inches, and the layers are bent down so as to be almost perpendicular to the surface. Some have thought that in this case we could determine how far the animal sank, by finding where the depressed laminæ of rock

cease to be fractured, and come out in regular curves, when they are split asunder. As far, indeed, as the foot did sink, we should not expect the rock would cleave in curved layers. But may not the narrow toes have bent down the layers so much, beneath where they reached, that they (i. e. the layers) would meet in an angle at the bottom so acute, that, when the rock was split open, they would break across rather than cleave asunder? In such a case, we should infer by this rule that the animal sank deeper than was the fact. And, indeed, I have sometimes found the print of a lateral toe, for instance, showing a perfectly continuous lamination across its depression, while that of the middle toe, nearly an inch deeper, was fractured. Although, therefore, this principle does help us somewhat in determining the layer on which the animal trod, it cannot be implicitly followed. If possible, we should obtain dissections of the track from top to bottom; and by combining the impressions on the successive layers, we shall probably get an accurate view of the entire foot. On one layer we may find a mere digitigrade, and on another or higher layer a plantigrade, impression; on one a heel, or a fourth toe, and on another neither. I think it true in general, however, that the layer on which the animal trod was usually nearer the bottom of the impressions than the top.

Those who have seen the manner in which successive layers of copper, deposited in the process of electro-metallurgy, retain the slightest markings upon the surface, will readily conceive that fine mud would do the same; less perfectly, indeed, but still so as to preserve the form of a track through many successive layers. On this ground, they will not be surprised that several layers often present the track with so nearly equal distinctness, that the one originally impressed can no more be distinguished, than the film

of copper that was first deposited can be from those superimposed afterwards.

The oblique direction in which the impressions often pass through successive layers, while their distinctness is not impaired, is a matter of surprise, and not so easily explained. Sometimes the track seems to advance, and sometimes to recede, and sometimes to move laterally on the successive layers, taking the lowest one as the fixed basis. This might proceed in part from the oblique direction in which the foot of the animal was exerted; as when running, for instance, the impression would be made so as to reach the successive layers farther and farther backward, because the legs incline forward; or suppose the surface to be inclined, and the animal going directly or obliquely up or down upon it. It is clear that the impression, in such case, would be communicated to the successive layers obliquely to the surface, so as to produce the phenomena which we actually observe. Again, if the tracks be made beneath the water, on light, loamy mud, it is easy to see that waves or currents might produce slight movements in the successive deposits, without destroying the impressions. Or if the surface were slightly inclined, gravity would produce the same effect on such mobile materials.

In general, we find but little difference in the size of the tracks on successive layers; yet, upon the whole, the tendency is rather to enlarge downwards. Decidedly the most striking example of this which I have noticed is represented in Plate 17, figs. 3 and 4, which are one half the natural size. Fig. 3 shows a track of *Ornithopus gallinaceus*, or of *Triænopus Emmonsianus*, I am not certain which, on an upper surface; fig. 4 shows the same, as it appears in relief, only one inch lower. The latter is the most dis-

tinct; and hence I doubt not that the upper track is smaller chiefly from the filling in of materials upon the original impression.

These examples, to which I might add more, show how careful we ought to be not to confound the impressions of the same track on different layers with different species. Nothing but long experience in ichnolithological researches will prevent such mistakes.

The number of toes (to return to the character which we were considering) varies from three to five; though, if the sketches on Plate 18 are the tracks of animals, we might call them didactylous. But they are so anomalous that I leave them out of the account, especially as they may belong to invertebrate tribes, if they are indeed real tracks.

From the details that have been given, we see that this character (the number of toes), although important, is in some cases of difficult determination.

4. *Absolute and relative length of the toes.* — In these characters there is a good deal of constancy; and hence they afford good grounds for specific and even generic distinctions. There are, however, some difficulties in the determination of these points. One is, the uncertainty that often exists, whether the track before us exhibits the very surface on which the animal trod. If it be above or below that plane, the toes will always be too short, although their relative length (the most important character) may not be essentially altered. But the greatest difficulty lies in determining how far backward the toes extend; that is, where the toes end and the heel begins. In the thick-toed tracks, this point can generally be decided with accuracy; though it hardly can be in the case of the anomalous *Otozoum.* But in the narrow-toed tracks, especially if they are digitigrade, and if their divarication is small, we can get only an approximate measurement of the length of the toes. The

rule which I have usually followed, where it could be adopted, has been, to measure the lengths of the toes of the leptodactylous tracks, from the point where the lateral front toes prolonged backward cross each other. This at least does well for the relative, if not for the absolute, length of the toes.

These characters are more important and more easily ascertained in those tracks which have only three toes directed forwards, and these nearly straight, than in those with a greater number directed forward, or which are much curved. In the first-named tracks, I find the fourth or hind toe always the shortest; the inner toe, of the three directed forward, the next longest; the outer one, still longer; and the middle one, the longest of all. This, I believe, agrees with the relative length of the toes of birds. Where four toes are directed forward, as Plate 15, figs. 6 – 9, Plate 16, figs. 4 – 6, and also Plate 11, figs. 1 and 2, the same order is observed. It is generally the same in the five-toed species, as Plate 13, fig. 2, and Plate 14, fig. 1. But sometimes, as in Plate 16, fig. 2, the outer toe but one is longest, and the outer one much the shortest, as in many of the living Ranidæ.

5. *Divarication of the lateral toes.* — In many living species, as, for example, the Palmipedes among birds, this is a very constant and reliable characteristic. Nor is this constancy confined to the web-footed animals. Where the toes are free, they diverge at a pretty constant angle; and so it seems to be with the fossil footmarks. I speak now of those where three toes are directed forward; for the chief application and use of this character are confined to these. They do, indeed, diverge a few degrees more or less in different specimens; but the variation is so limited, that a practised eye often recognizes a species by this mark. The angle is measured by lines drawn from the tips of the lateral toes to the middle of their posterior extremity.

6. *Angle made by the inner and middle toe, and the outer and middle toe.* — These angles are perhaps not quite as constant as that between the lateral toes; for in treading upon the mud, the strain upon the foot seems sometimes to have varied a little the position of the middle toe. Still, this character ought not to be neglected. In some instances, the curvature of the toes is so great, that it is difficult to measure the angles described under this and the preceding heads. But I have made it a rule to draw the lines forming the angles, from the middle of the toes, at their origin, to their tips.

7. *Projection of the middle toe beyond the lateral ones.* — This is not exactly equivalent to the difference in length between the middle and lateral toes, because the middle toe generally does not reach backward so far as the others. It is an important and constant character, and serves to distinguish several species; as the *Argozoum dispari-digitatum* from the *A. pari-digitatum.*

8. *Distance between the tips of the lateral toes.* — This is determined by the angle of divarication and the length of the lateral toes; but as it would need the solution of a case in trigonometry, it is easier to measure the distance; for it is useful in comparing one track with another.

9. *Distance between the tips of the middle and the inner and outer toes.* — These elements are also determined by the previous ones; but it is more convenient to measure than to calculate them. It is obvious that they are among the permanent characters, and therefore useful for settling the genus and species.

10. *Position and direction of the hind toe.* — This character applies only to those tracks that have three toes directed forward, and a single one behind. And it is obvious that the latter may have a great variety of positions and directions, and furnish, therefore, (since these characters are constant in the same species,) good

indices of different species. In many species of birds, the hind toe is simply the outer toe prolonged backwards, bringing the fourth toe (*pouce* of the French) always on the inside of the foot. And this is its situation in the fossil tracks; as in the *Ornithopus Adamsonus, gallinaceus, gracilior*, and *loripes*, Plate 8, figs. 1–4. In the *Plectropus minitans* and *longipes* it is short, and proceeds from a long heel, a little behind the origin of the toes, at right angles nearly to the heel, like the spur of the domestic cock. Plate 8, fig. 4, and Plate 9, fig. 3. In the *Triænopus Baileyanus* (Plate 10, fig. 4), it is very slender, proceeding from about the same place on a long heel, but directed forwards, so as to make quite an acute angle with the heel. In the *Triænopus Emmonsianus* (Plate 10, fig. 5), it proceeds from the end of the heel, and is directed somewhat backwards, so as to form with the heel on the anterior side an obtuse angle. In the *Polemarchus gigas* (Plate 9, fig. 1), this toe, which is quite stout, proceeds laterally from a very thick, rounded heel, at right angles to the axis of the foot. When this toe runs directly backward, it is difficult to distinguish it from a narrow heel; as in the *Macropterna rhynchosauroidea*, Plate 15, fig. 9. In this case I have indeed considered this projection as a heel, as the generic name implies. But the track of the snow-bird (*Fringilla Hudsonia*) is almost exactly like fig. 9, except the short outer toe; and it is a hind toe that makes the posterior impression. (See Transactions of the Association of American Geologists and Naturalists, Plate 11, fig. 8.)

In dissecting some specimens of *Plectropus*, I have been struck with another fact. On the highest layer the fourth toe appears to project at right angles with the heel, and some distance back from the roots of the other toes. But a little farther down we find its extremity turned backward, and its other end forward, until at

length it lies nearly on a line of the outer toe backward, which is a characteristic of another genus, the *Ornithopus;* and as the heel frequently disappears, the track is likely to be confounded with the *Ornithopus gallinaceus* (Plate 8, fig. 1), although generally they appear very much unlike. This singular change of position in the hind toe I find it very difficult to explain by any of the hypotheses which I have suggested above, in describing the fourth character.

11. *Character of the claw.* — This embraces its length and width; yet, with one exception, the length only is noticed. In the genus *Æthyopus*, the width of the claw indicates, if I mistake not, that it was winged. It is only in the pachydactylous tracks that the length of the claw, if it existed, can be ascertained, except in the *Argozoum Redfieldianum*, where a single specimen reveals it; and I doubt not it exists in all the leptodactylous feet, whose extremities are always acuminated.

The ratio between the length of the claw and that of the foot, in all the species where claws have been measured, is as follows: —

Brontozoum giganteum	9.9
" Sillimanium	6.75
" expansum	5.9
" gracillimum	6.2
" parallelum	8.1
Æthyopus Lyellianus	6.2
" minor	5.7
Argozoum Redfieldianum	6.2

These numbers do not differ from one another more, perhaps, than can be explained by uncertainties of measurement, which in the case of the claw must be considerable. Hence we may conclude that the length of the claw varies in the same proportion as that of the foot; at least, as nearly so as in living animals.

12. *Width of the toes.* — I have attempted to apply this character only to the pachydactylous tracks, as the others are so nearly alike, and so narrow, that no importance would attach to the measurements. The numbers given in the description of the several species of thick-toed animals are obtained from the same specimen, and merely indicate the greatest and least breadth of the phalangeal protuberances. Usually these measurements can be made with a good degree of accuracy, and therefore this character is one of considerable importance.

The following numbers express the ratio between the average width of the toes in these several tracks, and the length of the foot: —

Brontozoum giganteum	8.2
" Sillimanium	10.0
" expansum	5.8
" gracillimum	6.2
" parallelum	7.5
Æthyopus Lyellianus	5.8
" minor	5.3

It is clear that the great differences in these ratios cannot be explained by inaccuracies of measurement; and hence the thickness or breadth of the toes is a good character by which to distinguish species; as, indeed, an inspection of the outlines of the pachydactylous tracks on Plates 1, 2, and 3, will evince.

13. *Number and length of the phalangeal expansions.* — These points can of course be determined only in the thick-toed species; but then they are of great importance, especially the number of expansions on different toes; for in living animals it is well known that this character determines sometimes the class to which an individual belongs, and in the fossil footmarks this is the main

argument that leads to the conclusion that some of them were made by birds.

In estimating the number of phalanges from the tubercular expansions in the footmarks, I have supposed that the ungual and penultimate phalanges would make but one impression; and in general this conclusion is borne out by an examination of the feet of living animals.

It is also sometimes difficult to distinguish between impressions made by the phalanges, and those of the metacarpal or metatarsal bones. The tracks of the anomalous *Otozoum Moodii* exhibit this difficulty more distinctly than any other, as the detailed description of that species will show. Plate 12.

The number of phalangeal impressions on the tracks is greatest in the outer toe in all cases yet met with; and hence they are usually less distinct there, — so indistinct often that their measurement is difficult; and, indeed, the mere length of these impressions has not as yet been applied as a generic or specific distinction.

14. *Character of the heel.* — The fossil footmarks show much variety in this part, and being a constant part, it is of much value in determining the nature of the animal. In very many cases, the metacarpal or metatarsal bones seem to have been placed in so oblique a position, that neither they, nor the integuments beneath them, reached the ground; and we have accordingly only the imprint of the toes, as in *Platypterna tenuis* (Plate 7, fig. 2) and *Argozoum minimum* (Plate 6, fig. 5); that is, the feet were digitigrade. Indeed, in some cases the middle toe seems to have been articulated so high to the metatarsus or metacarpus, that it reached the ground only a good deal in advance, a striking example of which is shown in the *Typopus abnormis* (Plate 10, fig. 6).

A more common case is where the cushion beneath the metacarpal or metatarsal bones made an impression, but the bones themselves left no distinct imprint. This was usually the case with the pachydactylous tracks. But in two species at least, viz. the *Brontozoum Sillimanium* and *B. parallelum*, a distinct impression remains of the double-headed extremity of what was probably a tarso-metatarsal bone (Plate 3, figs. 2 and 4); for, besides these two rounded impressions, we have the four others in the outer toe which all the other tracks exhibit. Many of the leptodactylous tracks exhibit an impression of the cushion beneath the bones that lie behind the toes, forming a heel which slopes upward and backward so gradually, that it is impossible to say exactly where it terminates. For the mud yielded a little beyond the margin of the track, and this fact, in many instances, is a great hindrance to finding out the exact size and shape of the foot, and moreover is the grand difficulty of giving a satisfactory representation of these tracks. For this reason, I have in many instances, in the accompanying sketches, left the posterior part of the heel without an outline; as in *Platypterna tenuis*, *Ornithopus Adamsanus*, and some others.

In other cases, the posterior margin of a rounded heel is strongly marked, not, as we might at first suppose, because the animal sunk deeper on account of the peculiar state of the mud, but because it was a heavier animal, and one that trod more upon his heel; for we find the same deep impression wherever it trod. Examples of this sort are *Polemarchus gigas*, *Palamopus Dananus*, and sometimes *Triænopus Emmonsianus*, Plates 9, 10, and 11.

A few species present us with a heel of a very peculiar character, of whose exact nature I am yet in doubt. Just behind the point where the toes originate, the surface in the track rises above the

general level of the stone, while behind this ridge is a depression, in the bottom of which are minute ridges, radiating backward a considerable distance, which I have represented on Plate 5 by lines, the whole heel having the appearance of a brush. I formerly suggested, that this might have been produced by coarse hairs upon the animal's heel; but I now give up that idea, and imagine it to have been produced by radiating rugosities on the heel, or by the partial adhesion of the mud to the heel, as the animal raised its foot, conjoined with the subsequent action of the water; and I have sometimes thought it possible that the whole might be merely slight ripple-marks. But whatever may have been the origin of these marks, we may be sure that a large and rather remarkable heel belonged to the animal.

The long and narrow heel is a common one in these footmarks. In many instances, it seems to have been made by a long metatarsal or metacarpal bone, which did not lie horizontally upon the ground, but was inclined at various angles, according to the manner in which the animal pressed upon it, and moved forward. Hence the imprint would vary in different specimens, and its posterior termination be difficult to fix exactly. This character is shown on figs. 2 and 3, Plate 9, of *Plectropus minitans*, where it is obvious that the heel lay in a sloping position. In the *Anomœpus scambus* the whole of the tarsal or carpal joint is sometimes exhibited, and a part of the fore leg, as in Plate 13, fig. 4. At other times we see a graceful swelling out of the heel a little in advance of the tarsal or carpal joint, as in figs. 3 and 1 of *Anomœpus scambus*. The same is sometimes seen on *Plectropus minitans*, Plate 10, fig. 1.

The long heel of the hind foot of *Macropterna*, as already observed, may have been a toe; indeed, it bears a strong resemblance to the posterior toe on the hind foot of the *Phyllurus Milii*

and *Cuvieri* (*Dictionnaire Classique d'Histoire Naturelle*, Plate 120), which are lizards.

In some of the quadrupeds, the heel differs in the hind and fore feet; as, for example, the *Macropterna recta* and *divaricans* (Plate 15, figs. 6 and 7); the one being long, and the other rounded. The heel of the *Typopus abnormis* appears to come under the long variety; but it is very anomalous (Plate 10, fig. 6); as also is that of the unnamed track on Plate 15, fig. 2.

The difference between the heel of the fore and hind foot is likewise well exhibited in the *Anomœpus scambus*, and *Ancyropus heteroclitus*, Plate 13, figs. 1–6, and Plate 15, figs. 3 and 4. This character alone would form a good one for generic, as well as specific distinctions.

15. *Irregularities of the under side of the foot.* — The depth of the impression in the rock, made by the different parts of the foot, show which of them projected farthest downward. In this way we ascertain that usually the middle toe was rather the most prominent on the bottom of the foot; at least, most of the weight of the animal pressed upon it; for we find, as already stated, that as we cleave off successive layers of the rock, the middle toe remains longer than the others. And of the middle toe, its central parts make the deepest impression; showing that that part bent downwards most. Of the toes, the fourth, or hind one (where three are directed forward), disappears first; showing that its articulation was higher up than the others. The heel vanishes next; proving that it was placed on a higher level than the body of the foot.

One cannot inspect a series of specimens of footmarks without seeing at once that a part of the animals that impressed them were plantigrade and a part digitigrade. Of the former, all the pachydactylous tracks (*Brontozoum* and *Otozoum*) are examples;

of the latter, the genera *Argozoum* and *Platypterna*, on Plates 6 and 7, furnish examples.

But there is an intermediate and remarkable variety, in which the heel and toes made a deep impression, but a space between them is left unimpressed, and not unfrequently rising above the original surface, either in a curve or a ridge. We have examples of this in *Steropezoum ingens* and *elegans* (Plate 5), in *Harpedactylus concameratus* (Plate 14, fig. 3), and in *Triænopus Baileyanus* and *Emmonsianus* (Plate 10, figs. 4 and 5). In such cases it cannot be doubted that the long os calcis, or sometimes perhaps the carpal or tarsal bone, which formed the heel, was so articulated to the other bones of the foot as to constitute an arch, or even to form an angle, considerably acute, as in some quadrupeds; so that when the mud was impressed by the heel and the toes, it would be crowded upwards between them. This would exactly explain the appearance of some of the tracks above referred to; and it gives us an accurate view of the character of the bottom of the foot, and to some extent of its osseous structure. Sometimes the elevation of the rock, behind the toes, is irregular; indicating a corresponding irregularity on the bottom of the foot, as in *Steropezoum elegans*, Plate 5, fig. 2.

16. *Versed sine of the curvature of the toes.* — Some species of the footmarks are remarkable for the curvature of the toes. In the tracks with three toes directed forward, the middle toe always curves towards the line of direction on which the animal was advancing, and the lateral toes usually curve outwards near their tips. (See the figures of *Steropezoum ingens* and *elegans*, *Argozoum Redfieldianum*, the species of *Platypterna*, and especially of *Ornithopus loripes*, Plate 5, figs. 1 and 2, Plate 6, fig. 1, Plate 7, figs. 1 – 4, and Plate 8, fig. 3.)

In *Polemarchus gigas*, the outer toe curves slightly inwards like the others (Plate 9, fig. 1). In most of the four and five-toed tracks, the curvature is all one way, so as to make the curves of the several toes somewhat concentric; sometimes towards the line of direction, as in the species of *Harpedactylus* (Plate 14, figs. 2 and 3); at other times it is away from the line of direction, as in *Anomœpus Barrattii* (Plate 14, fig. 1) and *Ancyropus heteroclitus* (Plate 15, fig. 3). The curvature of the hind toe is usually so small, that I have not attempted to measure it.

If a straight line be drawn from the root to the tip of the toe, and another perpendicular to it where the curve is most distant, the length of this last line, measured from the centre of the toe, I call the *versed sine*.

I have sometimes suspected that this curvature resulted from the position of the animal's feet in relation to the line of direction; so that when it made a muscular effort to urge forwards the body, it would throw the toes into a curved position. But upon reflection, such a movement, it seems to me, would cause the toes to slide so much, that some vestige of the movement would remain, which I have never seen. I rather incline to the opinion, therefore, that this curvature is the natural state of the foot, and such as we see in many reptiles.

17. *Angle made by the axis of the foot with the line of direction.* — By the line of direction, I mean the course taken by the animal as it walked along the surface. To determine this accurately, we must have at least three tracks, and if possible four. The axis of the foot is a line drawn from the middle of the heel to the tip of the longest toe. Now in some species of animals, as they walk, these two lines nearly or quite coincide; as in the Grallæ among birds. But in other animals, with short legs, or

those whose feet diverge from the axis of the body, the divarication between these lines may be quite large. Nay, in some reptiles (ex gr. *Algyra barbarica*, Griffith's Cuvier, Vol. IX., p. 212, represented on Plate 23, fig. 6, of this paper), the hind foot is so situated, that it makes a very obtuse angle with the line of direction; and, in fact, the hind and fore feet point in nearly opposite directions; so that from the tracks alone one cannot determine in which direction the animal moved. It is obvious, then, that this is an important character, sufficient to distinguish species, and even genera.

18. *Distance of the middle of the heel, or posterior part of the foot, from the line of direction.* — I might have selected the tip of the longest toe as the point from which to measure, instead of the middle of the heel. But whichever extremity of the foot is used, the position of the other end is fixed, if we know the divarication between the axis of the foot and line of direction. And it is obvious that the distance to the right and left of the line of direction, at which we find the tracks, will depend partly and mainly upon the distance between the points of insertion of the legs upon the animal's body, and partly upon their length. Hence it must be a constant character, and cannot vary much in the same animal, except, perhaps, in some of the sprawling quadrupeds. I have never depended upon it alone to distinguish species; but I think it might be safely done, when the character is well marked.

19. *Length of the step.* — By running the eye over the column which shows the ratio between the length of the foot and the step, in the table of the characters of species, annexed to this paper, it will be seen that there is a general correspondence between the length of the foot and of the step. Yet the differences in the ratios make it equally obvious, that some of the animals were short-

legged, and some long-legged. Some may suppose that these differences only show that the animals moved with different rapidity at different times. There is, indeed, a considerable diversity in the length of the step of the same species on different specimens; but such cases as the *Brontozoum parallelum, Typopus abnormis, Anisopus Deweyanus*, and *gracilis*, at one extreme, and *Otozoum Moodii* at the other, make it evident that each animal had its peculiar type of progress and of stride. Yet there is so much difference in that stride, at different times, that I have not depended on that character alone to establish a species.

In giving the length of the step in the quadrupedal tracks, I have measured from track to track of the same foot.

20. *Size of the foot.* In a few instances the species of footmarks scarcely differ except in size; the best example of which is in the genus *Steropezoum*, whose three species (Plate 5, figs. 1 – 3) resemble one another in form, although I have seldom seen the peculiar heel of the *ingens* and *elegans* upon the *elegantius*, and the first two differ considerably in the ratio between the length of the middle toe and its extension beyond the two others. The question arises, whether the smaller species should not be considered as the young of the other. This is possible. But then we ought to find specimens of every intermediate size, which has not yet been done. And besides, is it probable that very young animals would often frequent such thoroughfares as the localities of footmarks seem to have been, where so many sorts of animals resorted, and where, in the dearth of food that must sometimes have existed, the young ones must often have been devoured if present? Are living animals wont to bring their offspring into such places, till they have attained considerable size?

Considerations like these have led me to the conclusion, that

probably, when tracks of the same form differ a good deal in size, they are made by different species, perhaps of the same genus. Yet in view of the difficulty of proving this, I have avoided depending upon this character alone, except, perhaps, in the single case of the *Steropezoum elegantius;* and as to this species I feel no great confidence. Nevertheless, the tracks of many species, and even genera, of living animals differ less than the *S. elegans* and *elegantius.*

21. *Character of the integuments of the foot.* — In a few instances, the ridges, furrows, pits, and anfractuosities of the animal's feet are exhibited upon its tracks. As yet, however, I have not been able to employ this character as a distinctive mark of the nature of the animal, partly, perhaps, because I have not had opportunity to make extensive comparisons with the feet of living animals on this point.

22. *Coprolites.* — A few coprolites have been discovered of one species of these animals, the *Argozoum Redfieldianum;* and Dr. Dana has deduced from their analysis a beautiful argument to show the nature of the animal that produced them. But its elucidation has been presented fully in the *American Journal of Science,* Vol. XLVIII. p. 46.

23. *Means of distinguishing between the tracks of bipeds and quadrupeds.* — Persons who have never turned their attention to this subject will probably suppose that this is a very easy matter. But they would think otherwise should they attempt to make the distinction; especially in many cases of fossil footmarks, where imperfect specimens are often all that can be obtained. And even in studying the tracks of living animals, we shall sometimes be liable to confound those of bipeds and quadrupeds. Thus the dog, for instance, sometimes moves along without bringing all his

feet to the ground, and by a sort of double hop, which produces a series of tracks of a very dubious character.

The regular alternation of the right and left foot, on each side of the line of direction, is a most decisive indication of the biped origin of a row of tracks. And usually the right and left foot can be readily distinguished. In the pachydactylous tracks, the two protuberances of the inner toe, while the outer one has four, settle this point. When a fourth toe points backward, we know which foot made the impression, because that toe is always on the inside. So it is where it proceeds from a long heel. If the toes are curved, the curvature of the middle toe is generally inward in bipeds; that is, when the toes curve to the left, it is the right foot, and *vice versâ;* and, finally, a less certain mark to guide us is the relative length of the toes, since the inner toe is almost always shortest. This is less certain only because we cannot always determine which toe is the shortest.

The regular movement of a quadruped in walking or running, not leaping, produces two nearly parallel rows of tracks, of the character represented on Plate 19, fig. 1. Here, as the fore foot is lifted up to advance, the hind foot is brought up nearly to the same place; and hence it is, that we have put unequal intervals between the tracks. But some animals — the cat, for instance — are frequently in the habit of bringing the hind foot so exactly into the place just vacated by the fore one, that it is only by careful examination, upon a long row of tracks, that the double impression can be recognized; and moreover, some animals of this sort bring their tracks so nearly into a single line, that a biped origin is readily ascribed to them. The sketch on Plate 19, fig. 2, is not an exaggeration of some cases of this sort, which have fallen under my notice. Here it is only the fifth im-

pression that gives any evidence of quadrupedal origin, save in the number of the toes; which, indeed, in living animals, is a good criterion for the most part. But we shall see in the sequel that some quadrupeds have lived with only three toes (at least on the fore feet) directed forward, and some bipeds with at least four toes directed forward (e. g. the *Macropterna* and *Otozoum*); so that the number of toes is a somewhat equivocal character.

There are some quadrupedal animals, whose tracks would be arranged in two rows; not, as first described, with two approximate tracks succeeded by a wide interval, but probably, for the most part, equidistant. The extreme tracks on Plate 19, fig. 3 (that is, those at the ends of the rows), were copied from the feet of the banded Proteus (*Menobranchus lateralis*), sent to me alive, in April, 1848, by Rev. J. W. Ray, from Oswego, N. Y., where it was caught in the autumn of 1847. The sketches were obtained by placing the animal, soon after death, in a natural position, such as I had often seen it assume when alive. They are shown on the plate of the natural size. Now as this animal's legs are not more than an inch or two long, it is clear that in walking he could not bring up the hind foot half way to the fore one, but might be expected to leave its tracks somewhat as represented by the dotted impressions on the plate, though probably they would not be as nearly equidistant as the sketches are. It is plain, however, that such an animal would leave two rows of tracks, not alternating, nor arranged as in fig. 1 of the same plate. Among the fossil footmarks, we have an analogous case in the tracks of *Macropterna divaricans* (leaving out the fore feet), as is shown on Plate 19, fig. 5; and also, more exactly, in *Ancyropus heteroclitus*, shown on Plate 19, fig. 4.

The angle made by the line of direction and the axis of the feet, as well as the distance of the feet laterally from that line, are

other means of distinguishing bipedal from quadrupedal tracks. For in the latter the axis of the feet usually lies more oblique to the line of direction, and they are more distant from it, than in the former. In some of the tortoise tribe, for instance, the feet point almost at right angles to the line of direction, and are very wide apart. In this case, however, we have double rows of tracks, which at once remove all doubt.

Conclusion. — Such are the characters on which I rely to discriminate and describe the animals that made the fossil footmarks. They depend for their value upon the principles of comparative anatomy and zoölogy. They assume that such relations exist between the feet and general structure of animals, that, knowing the one, we can usually determine the other. I acknowledge these relations to be sometimes too obscure to conduct us to an infallible result. But the same is true in respect to most of the parts of animals from which the comparative anatomist draws his conclusions. We cannot, indeed, depend upon any *one* of the characters derived from the feet to conduct us to certain results. But when several conspire to the same end, we feel stronger confidence in the conclusion. If applied to living animals, it seems to me they would enable us to decide with a good degree of confidence upon the following points: —

1. Whether the animal is a biped or a quadruped.
2. Whether vertebral or invertebral.
3. To what class it belongs.
4. To what order or family. Here, however, I think we should often fail.
5. To what genus. Here, also, I think we should not unfrequently confound different genera; for the feet of many genera are too nearly alike to be distinguished by their tracks. As ap-

plied to fossil footmarks, however, the only result of the mistake would be to lead us to describe too few genera; that is, to confound more than one genus under one name, — an error far more venial in natural history than its opposite.

6. To what species. And since a specific description embraces the whole animal, — or, in the present instance, its whole track, — I think we can be more sure of being led right by these characters as to species, than as to genera.

Adopting these principles as my guide, I have arranged the fossil footmarks of the United States, mainly of New England, according to the following synopsis. I have no great confidence in the arrangement into groups, except in a few instances; and only in a few cases have I ventured to attach names to the groups. In the genera and species I have more confidence.

Group I. (STRUTHIONIDÆ ?)

Genus 1. BRONTOZOUM (Βρόντης and ζῶον).

1. B. giganteum.
2. B. Sillimanium.
3. B. loxonyx (λοξός, *oblique*, and ὄνυξ, *a claw*).
4. B. expansum.
5. B. gracillimum.
6. B. parallelum.

Genus 2. ÆTHIOPUS (αἴθυια, *fulica*, and πούς).

1. Æ. Lyellianus.
2. Æ. minor.

Group II.

Genus 3. STEROPEZOUM (Στερόπης and ζῶον).

1. S. ingens.
2. S. elegans.
3. S. elegantius.

Genus 4. ARGOZOUM (Ἄργης and ζῶον).

1. A. Redfieldianum.
2. A. dispari-digitatum.
3. A. pari-digitatum.
4. A. minimum.

Genus 5. PLATYPTERNA (πλατύς and πτέρνα).

1. P. Deaniana.
2. P. tenuis.
3. P. delicatula.

GROUP III.

Genus 6. ORNITHOPUS (ὄρνις and ποῦς).

1. O. Adamsanus.
2. O. gallinaceus.
3. O. gracilior.
4. O. loripes.
5. O. rectus.*

GROUP IV.

Genus 7. POLEMARCHUS (πολέμαρχος).

1. P. gigas.

Genus 8. PLECTROPUS (πλῆκτρον and ποῦς).

1. P. minitans.
2. P. longipes.

Genus 9. TRIÆNOPUS (τρίαινα and ποῦς).

1. T. Baileyanus.
2. T. Emmonsianus.

* Discovered (as also *Harpedactylus rectus*, p. 167) while this paper was passing through the press. Hence the number of species in this synopsis (fifty-one), exceeds by two the number stated at the beginning of this memoir.

Genus 10. HARPEDACTYLUS (ἅρπη and δάκτυλος).

1. H. gracilis.
2. H. concameratus.
3. H. rectus.*

Appendix to this Group.

Genus 11. TYPOPUS (τύπος and ποῦς).

1. T. abnormis.

GROUP V. (BIPEDAL BATRACHIANS ?)

Genus 12. OTOZOUM (Ὦτος and ζῶον).

1. O. Moodii.

Genus 13. PALAMOPUS (παλάμη and ποῦς).

1. P. Dananus.

GROUP VI. (QUADRUPEDAL BATRACHIANS.)

Genus 14. THENAROPUS, *King* (θέναρ and ποῦς).

1. T. heterodactylus.

Genus 15. ANOMŒPUS (ἀνόμοιος and ποῦς).

1. A. scambus.
2. A. Barrattii.

Genus 16. ANISOPUS (ἄνισος and ποῦς).

1. A. Deweyanus.
2. A. gracilis.

Genus 17. HOPLICHNUS (ὁπλή and ἴχνος).

1. H. quadrupedans.

Group VII. (LACERTILIANS ?)

Genus 18. MACROPTERNA (μακρός and πτέρνα).

1. M. rhynchosauroidea.
2. M. recta.
3. M. divaricans.

Genus 19. XIPHOPEZA (ξίφος and πέζα).

1. X. triplex.

Group VIII. (CHELONIANS.)

Genus 20. ANCYROPUS (ἄγκυρα and ποῦς).

1. A. heteroclitus.

Genus 21. HELCURA (ἕλκω and οὐρά).

1. H. littoralis.

Group IX. (ANNELIDS or MOLLUSCS.)

Genus 22. HERPYSTEZOUM (ἑρπυστής and ζῶον).

1. H. Marshii.
2. H. minutum.

Group X.

Genus 23. HARPAGOPUS (ἁρπάγη and ποῦς).

1. H. giganteus.
2. H. Hudsonius.
3. H. dubius.

I now proceed to describe in a systematic manner the above groups, genera, and species. Their affinities to existing animals will be pointed out, so far as they can be ascertained.

Group I. STRUTHIONIDÆ.

Animal vertebrated, bipedal, tridactylous, pachydactylous.

Genus I. BRONTOZOUM.

Foot tridactylous, pachydactylous, tubercular-clawed; inner toe shortest; all of them directed forward. Phalangeal expansions on the inner toe, two; on the middle toe, three; on the outer toe, four; corresponding to the number of phalanges, except the distal expansion, which was probably made by the two extreme phalanges. Lower extremity of the tarso-metatarsal bone double-headed; rarely making a distinct impression through the cushion beneath. Cushion sloping upwards posteriorly. Claws on the lateral toes a little outside of their axes; on the middle toe, a little towards its inner side.

Species I. Brontozoum giganteum. (Pl. I. Fig. 1.)

Ornithichnites giganteus, Am. Journal of Science, Vol. XXIX., Plate 1; and Buckland's Bridgewater Treatise, Plate 26^b.

Ornithoidichnites giganteus, Final Report on the Geology of Massachusetts, Plate 36, fig. 18.

Nos. 38 – 43, 128, 149, 150, 151, of specimens in the Cabinet of Amherst College.

Divarication of the lateral toes, 40°; of the inner and middle toes, 20° to 25°; of the outer and middle toes, 15°. Length of the middle toe, 12.5 inches; of the inner toe, 10 inches; of the outer toe, 12.5 inches; of the foot, 14 to 18 inches; of the step, 3 to 6 feet. Width of the toes, 2 to 3 inches; of the posterior part of the foot, 6.5 inches. Length of the claw, 1.75 inch. Distance between the tips of the lateral toes, 12

inches; between the tips of the outer and middle toes, 7 to 8 inches; between the inner and middle toes, 7.45 inches. Length of the middle toe beyond the lateral toes, 5.5 inches. Length of the proximal phalanx of the inner toe, 3.7 to 3.8 inches; of the penultimate and ultimate phalanges united, 3.7 to 4.7 inches; of the proximal phalanx of the middle toe, 2.8 to 4 inches; of the second phalanx, 3 to 3.1 inches; of the penultimate and ultimate phalanges united, 2.3 to 2.9 inches; of the proximal phalanx of the outer toe, 3.1 to 3.5 inches; of the second, 2.8 to 3.2 inches; of the third, 2 to 2.1 inches; of the penultimate and ultimate phalanges united, 2.3 to 2.5 inches. Angle between the line of direction and the axis of the foot, as the animal walked, 5° to 10°. Distance of the centre of the heel from the line of direction, 2 to 3 inches. Toes nearly straight; middle one slightly curved inwards. Claws nearly straight, and only slightly deflexed. Integuments of the under side of the foot papillose and striated. Animals gregarious. Track shown of the maximum size, with some of the striæ and papillæ, on Plate 1, fig. 1.

Remarks. — This enormous animal, whose feet were four or five times larger than those of the ostrich, seems to have been the most common of those whose tracks have been impressed upon the sandstone of the Connecticut valley; for its tracks are more abundant than those of almost any other species. They must have been the giant rulers of that valley. Their gregarious character appears from the fact, that, at some localities (Northampton, &c.), we find parallel rows of tracks a few feet distant from one another, and that, too, oblique somewhat to the line of coast at the time.

Localities. — Between the bridges over Connecticut and Deerfield Rivers, in the northeast part of Deerfield; at the Horse Race, in Gill; at Northampton, Chicopee Falls, Enfield Falls, and Wethersfield.

Species 2. BRONTOZOUM SILLIMANIUM. (Pl. III. Fig. 2.)

Ornithoidichnites tuberosus in part, and *O. cuneatus*, of Mass. Geol. Report, Plate 37, fig. 21, and Plate 38, fig. 22.

Ornithoidichnites Sillimani, Transactions of Association of Amer. Geol., p. 256.

Nos. 44, 47–52, 55, 56, 90, 126, 138, 144, 149, 173, 185, 186, 206, 209, 234, in Cabinet.

Divarication of the lateral toes, 30° to 40°; of the inner and middle toes, 20° to 30°; of the outer and middle toes, 10° to 20°. Length of the middle toe, 6 inches; of the inner toe, 4.4 inches; of the outer toe, 5.5 inches; of the foot, 8 inches; of the step, 18 to 20 inches; of the claw, 1 inch. Distance between the tips of the lateral toes, 5 inches; between the tips of the inner and middle toes, 4 inches; between the tips of the outer and middle toes, 3.5 inches. Projection of the middle toe beyond the lateral ones, 3 inches. Width of the toes, 1 to 1.9 inch. Length of the proximal phalanx of the inner toe, 0.9 to 1.6 inch; of the penultimate and ultimate phalanges united, 0.8 to 1.3 inch; of the proximal phalanx of the middle toe, 0.9 to 1.5 inch; of the second, 1 to 1.6 inch; of the penultimate and ultimate phalanges united, 0.8 to 1.7 inch; of the proximal phalanx of the outer toe, 0.7 to 0.9 inch; of the second phalanx, 0.7 to 0.8 inch; of the third, 0.6 to 1 inch; of the penultimate and ultimate phalanges united, 0.8 to 1.5 inch. Extremity of the tarso-metatarsal bone with two condyles for articulation with the toes. Axis of the foot nearly coincident with the line of direction. Claws nearly straight, and only slightly deflexed from the axis of the toes. Tracks shown, of the natural size, on Plate 3, fig. 2, which exhibits also an impression of the double-headed extremity of the tarso-metatarsal bone; copied from a specimen from South Hadley.

Remarks. — This species varies considerably in size, and its tracks are quite abundant at Turner's Falls and Northampton, and are found also at Wethersfield, Portland, and Middletown. It has also been found at Pompton, in New Jersey, by W. C. Redfield, Esq. (Am. Jour. Sci., Vol. XLIV. p. 134, and XLV. p. 315), and is the only species of this genus found out of the valley of Connecticut River. It is respectfully dedicated to Dr. Benjamin Silliman, of New Haven.

On Plate 24, fig. 5, is an outline of an interesting slab, less than two feet in diameter, discovered by Mr. Plinius Moody, in the north part of South Hadley, and deposited by him in Amherst College. It contains 20 tracks of this species on that small surface, in relief, many of them very distinct, brought to light by the action of water; the track being so much concreted as not to be washed away nor disintegrated. The tracks are not all on one layer.

Species 3. BRONTOZOUM LOXONYX. (Pl. II. Fig. 1, 2.)

Ornithichnites tuberosus in part, Am. Jour. Sci., Vol. XXIX. p. 318.

Ornithoidichnites tuberosus in part, Mass. Geol. Report, Plate 37, fig. 20.

Nos. 44–46, 53, 54, 187–190, in Cabinet.

Divarication of the lateral toes, 25° to 30°; of the inner and middle toes, 15° to 20°; of the middle and outer toes, 10°. Length of the middle toe, 6 inches; of the inner toe, 4.4 inches; of the outer toe, 5.5 inches; of the foot, 8 inches; of the claw, 1 inch; of the step, 30 inches. Distance between the tips of the lateral toes, 5.75 inches; between the tips of the inner and middle toes, 4 inches; between the tips of the middle and outer toes, 4 inches. Projection of the middle toe beyond the lateral

ones, 3 inches. Width of the toes, 1 to 1.9 inch. Length of the proximal phalanx of the inner toe, 1.6 inch; of the second and third phalanges, 1.6 inch; of the first of the middle toe, 1.6 inch; of the second, 1.7 inch; of the last two, 1.4 inch; of the first of the outer toe, 1 inch; of the second, 1.3 inch; of the third, 1.2 inch; of the last two, 1.5 inch. Toes straight; claws abnormal (bent), making an angle with the axis of the toes of from 30° to 40°. Axis of the foot and line of direction nearly coincident. Tracks shown, of the natural size, on Plate 2, fig. 1, from Mount Holyoke; and fig. 2, from Turner's Falls, which specimen was destitute of claws and less divaricate than fig. 1, but shows the phalangeal impressions very distinctly.

Localities. — Mount Holyoke, Northampton, Wethersfield, Turner's Falls, Horse Race, and South Hadley.

Remarks. — I have found more difficulty in fixing upon the distinctive characters of this and the species which precedes and follows it, than in respect to almost any other species founded on footmarks, because they seem to pass more or less into one another. Yet one sees that the footmarks could not have been made by the same species at different ages of growth. The present species is distinguished from the preceding by its larger size, the more massive character of the foot, and by an unusually oblique direction to the claws. It is also rather less divaricate. The oblique direction of the claws (from which the specific name is derived) may not be constant. It is quite obvious in the specimen from which Plate 2, fig. 1, was taken, as well as in all the specimens from the same locality, although these are few. That locality is a remarkable one, namely, the west precipitous side of Mount Holyoke, twenty rods north of Titan's Piazza, where the gray micaceous slate crops out below the trap, and only a few feet

below the latter occur the tracks. This is the only spot where footmarks are found in this valley beneath the trap; and it probably, though not necessarily, indicates an earlier existence of the animals than in those cases where the tracks lie above the trap.

Species 4. BRONTOZOUM EXPANSUM. (Pl. III. Fig. 1.)

Ornithoidichnites expansus, Mass. Geol. Rep., Plate 38, fig. 23.

Nos. 44, 59, 207, in Cabinet.

Divarication of the lateral toes, 50° to 70°; of the inner and middle toes, 25°; of the middle and outer toes, 30°. Length of the middle toe, 4.6 inches; of the inner toe, 3.2 inches; of the outer toe, 4.9 inches; of the claw, 1.1 inch; of the foot, 6 to 7 inches; of the step, 25 inches. Distance between the tips of the lateral toes, 6 inches; between the tips of the inner and middle toes, 4.2 inches; between the middle and outer toes, 3.4 inches. Projection of the middle toe beyond the lateral ones, 2.4 inches. Width of the toes, one inch to one and a half. Length of the proximal phalanx of the inner toe, 1.3 inch; of the last two, 1.2 inch; of the first on the middle toe, 1.4 inch; of the second, 1.3 inch; of the last two, 1.3 inch; of the first on the outer toe, 1.6 inch; of the second, 1.2 inch; of the third, 0.9 inch; of the last two, 1.3 inch. Toes straight; claws normal; that is, only slightly deflexed from the axis of the toes. Track shown, of the natural size, on Plate 3, fig. 1.

Remarks. — This species has a more massive foot than the B. Sillimanium; its divarication is greater, and its middle toe shorter. Yet it is not always easy to distinguish the two species. They occur at the same localities, but the former is much the more common.

Species 5. Brontozoum gracillimum. (Pl. II. Fig. 3.)

Ornithoidichnites gracillimus, Am. Jour. Sci., Vol. XLVII., Plate 3, fig. 4.

Nos. 89, 129, 130, 134, 135, 158, 167, in Cabinet.

Divarication of the lateral toes, 50°; of the inner and middle toes, 25°; of the middle and outer toes, 25°. Length of the middle toe, 2.2 inches; of the inner toe, 1.7 inch; of the outer toe, 2 inches; of the claw, 0.4 inch; of the foot, 2.5 inches; of the step, 7 to 8 inches. Distance between the tips of the lateral toes, 1.9 inch; between the tips of the inner and middle toes, 1.2 inch; between the tips of the outer and middle toes, 1.35 inch. Projection of the middle toe beyond the lateral ones, 0.9 inch. Width of the toes, 0.3 to 0.5 inch. Length of the proximal phalanx of the inner toe, 0.5 to 0.6 inch; of the last two, 0.4 to 0.5 inch; of the first on the middle toe, 0.5 to 0.6 inch; of the second, 0.4 to 0.5 inch; of the last two, 0.3 to 0.4 inch; of the first on the outer toe, 0.45 inch; of the second, 0.4 inch; of the third, 0.45 inch; of the last two, 0.6 inch. Toes straight; claws slightly abnormal. Angle between the line of direction and the axis of the foot, 0° to 10°. Distance of the heel from the line of direction, 0.8 inch. Track shown, of the natural size, on Plate 2, fig. 3.

Localities. — Turner's Falls, Chicopee Falls, Wethersfield.

Species 6. Brontozoum parallelum. (Pl. III. Figs. 3, 4.)

Figured and described in Am. Journal of Science, Vol. IV., New Series, p. 50.

Nos. 137, 234, in Cabinet.

Divarication of the lateral toes, 15° to 20°; of the inner and middle toes, 5° to 6°; of the outer and middle toes, 8° to 15°.

Length of the middle toe, 2 to 3 inches; of the inner toe, 1.5 to 2 inches; of the outer toe, 1.8 to 2.3 inches; of the claw, 0.4 inch; of the foot, 3 to 3.5 inches; of the step, 13 to 24 inches. Distance between the tips of the lateral toes, 1.5 to 1.6 inch; between the inner and middle toes, 1.7 inch; between the outer and middle toes, 1.6 inch. Projection of the middle toe beyond the lateral ones, 1.4 inch. Width of the toes, 0.4 to 0.6 inch. Length of the proximal phalanx of the inner toe, 0.8 inch; of the last two, 0.9 inch; of the first on the middle toe, 0.8 inch; of the second, 0.8 inch; of the last two, 0.8 inch; of the first on the outer toe, 0.55 inch; of the second, 0.4 inch; of the third, 0.4 inch; of the last two, 0.55 inch. Toes straight; claws somewhat abnormal. Axis of the foot and line of direction entirely coincident. Track shown, of the natural size, on Plate 3, figs. 3 and 4. Fig. 4 was copied from a specimen from South Hadley, and shows the impression of the double-headed extremity of the tarso-metatarsal bone, behind the phalangeal impressions.

Localities. — Turner's Falls, South Hadley.

Remarks. — Distinguished from all other species by the less divarication of the outer toes, and the great length of the step. I have reason to suppose that its most usual step was almost two feet. This would make its leg nearly four feet long; which is greater than that of the red flamingo.

Affinities of the Group. — The alternation of right and left feet proves the animals to have been bipeds. The number and position of the toes, but more eminently the number of phalanges in the several toes, ally the animals strongly to birds. The want of a hind toe, and the great length of most of the steps, ally them to Grallæ. The great thickness of the toes, and the great size of the feet, in some instances, taken in connection with the fact, that

the Struthionidæ have that low organization which might have enabled them to live almost as early as reptiles, renders it not improbable that these birds belonged to that family.

Though several facts as above stated afford a presumption that these animals were birds, yet the new developments that have come to my knowledge on this subject have left that opinion to rest mainly on one argument, namely, the number of phalanges in the toes; which, if we admit two phalanges to have made but one tubercular impression at the extremities of the toes, correspond to the feet of birds, and to those of no other animals. I should once have relied much on the mere fact that these animals were bipeds, to prove their ornithic type, taking existing animals as the basis of judgment. But, as I shall show farther on, we now know that some of these biped animals were probably batrachians, — certainly not birds. The trifid character of the toes in front is another character which in existing animals is confined to birds, with two or three unimportant exceptions. But, in one of the species to be described in this paper, we have a distinct tridactyle character to the fore foot, and yet we can prove beyond all question that it belonged to a quadruped. Upon the whole, though the evidence of the ornithic character of this group is narrowed down, it is still firm and substantial.

Sub-Group.

Characters. — Toes and claws winged. Other characters the same as the general group.

Genus II. ÆTHYOPUS.

Foot tridactylous, expanded, winged: phalangeal impressions in

the track shallow. (Other characters the same as those of the Brontozoum, except in respect to the extremity of the tarso-metatarsal bone, whose character in this genus has not been observed.)

Species I. ÆTHYOPUS LYELLIANUS. (Pl. IV. Fig. 1.)

Ornithoidichnites Lyellii, Transactions of Assoc. Amer. Geologists, Plate 11, fig. 1.

Nos. 57, 58, in Cabinet.

Divarication of the lateral toes, 35°; of the inner and middle toes, 15°; of the middle and outer toes, 20°. Length of the middle toe, 6.4 inches; of the inner toe, 4.2 inches; of the outer toe, 5.2 inches; of the claw, 1 inch; of the foot, 7 to 9 inches. Distance between the tips of the lateral toes, 4.8 inches; between the inner and middle toes, 4.1 inches; between the outer and middle toes, 3.9 inches. Projection of the middle toe beyond the lateral ones, 3.3 inches. Width of the toes, 1.1 to 1.8 inch. Length of the proximal phalanx of the inner toe, 1.6 inch; of the last two phalanges, 1.8 inch; of the first on the middle toe, 1.8 inch; of the second, 1.8 inch; of the last two, 1.7 inch; of the first on the outer toe, 1.2 inch; of the second, 1.2 inch; of the third, 1 inch; of the last two, 1.5 inch. Toes straight; flat beneath, winged. Claws winged, broad, unusually lateral in their origin. Track shown, of the natural size, on Plate 4, fig. 1.

This species is dedicated to Charles Lyell, Esq., of London, whose researches in respect to fossil footmarks have been very important.

Remarks. — This remarkably distinct species has been found only at Turner's Falls, and in single detached specimens; so that the length of the step has not been ascertained. As to the possibility of its being the *Brontozoum loxonyx,* see my remarks following the next species.

Species 2. ÆTHYOPUS MINOR. (Pl. IV. Fig. 2, 3.)

Ornithoidichnites fulicoides, Trans. Assoc. Amer. Geol., Plate 11, fig. 4.

Nos. 60 – 62, 130, 136, 137, 159, 209, in Cabinet.

Divarication of the lateral toes, 50° to 70°; of the inner and middle toes, 20° to 30°; of the middle and outer toes, 30° to 40°. Length of the middle toe, 3.2 inches; of the inner toe, 2.5 inches; of the outer toe, 2.9 inches; of the foot, 3.5 to 4 inches; of the step, 8 to 10 inches; of the claw, 0.7 inch. Distance between the tips of the lateral toes, 3.3 inches; between the inner and middle toes, 1.9 to 2 inches; between the middle and outer toes, 2.5 inches. Projection of the middle toe beyond the lateral ones, 1.5 inch. Width of the toes, 0.65 to 0.87 inch. Length of the first phalanx on the inner toe, 1.2 inch; of the last two, 0.5 inch; of the first on the middle toe, 1 inch; of the second, 0.5 inch; of the last two, 0.7 inch; of the first on the outer toe, 0.8 inch; of the second, 0.7 inch; of the third, 0.6 inch; of the last two, 0.5 inch. Toes straight, winged: claws normal, winged. Angle of the axis of the foot from the line of direction, from 5° to 10°; sometimes outward, and sometimes inward. Distance between the heel and the line of direction, 1.25 inch. Track shown, of the natural size, on Plate 4, figs. 2 and 3, which differ chiefly in size.

Localities. — Turner's Falls and South Hadley.

Remarks. — There is one supposition which would make the distinction between Brontozoum and Æthyopus an accidental circumstance. Mud, when trodden upon, may be in so plastic a state, that deep impressions made upon it would be partially filled by the gravity of the surrounding particles. Yet a superficial impression might remain, say of the foot of an animal, and this, becoming hardened, might present the appearance of winged toes. Of the

first species I have only a few specimens; yet they do not appear as if thus altered from a track of the *Brontozoum loxonyx*, which most resembles this in shape. The phalangeal impressions are distinct, and the mud must have been a fine, tenacious red clay, such as has left us in other species the most perfect tracks; even in some instances, the papillæ and striæ of the skin. The *Æthyopus minor* is a common track, though impressions of its claws are not often well exhibited. Yet when they are shown, they seem to have been produced by a marginal wing. The evidence of a wing along the toes is less obvious in this species. But, upon the whole, I have only slight doubts that the feet of these animals (birds) were winged.

Numerous rows of the tracks of this species are represented on Plate 20, fig. 10, and Plate 23, fig. 3, which give the outlines of slabs (the first in my collection, and the other in that of Mr. Marsh), containing tracks of other species of animals; two quadrupeds at least, the Anisopus and Helcura. Plate 24, fig. 3, is the outline of a small slab in Mr. Marsh's collection, remarkable for the great distance of the right and left tracks from the line of direction. Yet that they were made by right and left feet is evident from the number of phalangeal impressions on the toes. It seems difficult to suppose that it is not a distinct species from the A. minor; although that species commonly walked with feet wide apart.

Affinities of the Sub-Group. — The resemblance between the tracks of these animals and the feet of the *Fulica Americana*, or Coot, and of the Grebe or Dob Chick, *Podiceps Carolinensis*, is striking; and since other considerations (especially the number of phalanges) ally them to birds, it seems reasonable to conclude that the animals which made these tracks were closely allied to the Podicepidæ.

Table of the Ratio of the several Characters in the Species of this Group. — It will afford the zoölogist and comparative anatomist a better means of judging of the grounds on which the foregoing species have been proposed, to present at a glance, so far as it can be done in figures, the relations between the several characters in different species. I hope in this way to satisfy naturalists, that such differences in the tracks could not have belonged to mere varieties as to age or mode of progression, nor have resulted from the character of the mud, but must have required different species of animals to produce them. In other words, I hope to show that these differences are quite as great as they are between the tracks of different living species. In constructing the table, I have taken 100 as the highest number in the preceding details of the characters, and calculated the proportion which the same character in the other species bears to this maximum. It may happen, as in the second column, that a character is at a maximum in several species.

	Divarication of			Length of							Distance				Length of the phalanges of									
	The lateral toes.	The inner and middle.	The middle and outer.	The middle toe.	The inner.	The outer.	The foot.	The step.	The claw.	Middle toe beyond the rest.	Between the lateral toes.	Between the inner and middle.	Between the middle and outer.	Width of the toes.	The inner toes.		The middle toes.			The outer toes.				Ratio between the length of the foot and the step.
B. giganteum	50	60	43	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	3.4
B. Sillimanium	44	100	43	48	44	44	50	38	57	55	42	54	47	56	46	36	35	43	46	24	23	40	46	2.4
B. loxonyx	34	80	29	48	44	44	50	56	57	55	48	54	53	56	43	38	47	56	53	30	43	60	62	3.7
B. expansum	75	100	86	37	32	40	40	46	63	44	50	57	45	50	35	29	41	43	50	43	40	45	54	3.8
B. gracillimum	75	100	71	18	17	16	16	14	23	16	16	16	18	16	11	12	14	13	15	14	13	22	25	3.0
B. parallelum	22	22	33	20	18	16	20	34	23	26	12	23	21	20	21	21	24	26	32	17	13	20	23	5.8
Æth. Lyellianus	50	60	57	51	42	42	50		57	60	40	55	52	56	43	43	53	60	65	37	40	50	62	
Æth. minor	100	100	100	26	25	23	24	17	40	23	28	27	33	28	33	12	27	26	27	24	23	30	21	2.4

Group II.

Characters. — Tridactylous, leptodactylous, bipedal, vertebrated.

Genus I. STEROPEZOUM.

Toes somewhat keel-shaped; the middle and inner ones curved towards the line of direction; the outer one slightly bent from that line. Heel distinct and large; leaving an impression on mud of radiating ridges and furrows, sloping upwards very gradually behind, more abruptly before, leaving a ridge on the track, at least as high as the general surface, between the heel and the toes, which also slope upwards posteriorly. This ridge, however, has usually a depression in it, connecting the heel and the outer toe. But, upon the whole, we infer that the foot arches upwards between the toes and the heel, leaving, however, a slight ridge along its outer part. Bottom of the heel a little elevated above that of the toes.

Remark. — Of the nature of that structure of the heel, which produces on the track radiating ridges, somewhat resembling fine ripple-marks, I feel in doubt, yet am inclined to believe them the result of rugosities, or striæ and ridges on the heel.

Species 1. Steropezoum ingens. (Pl. V. Fig. 1.)

Ornithichnites ingens, Am. Jour. Science, Vol. XXIX. p. 319.
Ornithoidichnites ingens, Mass. Geol. Rep., Plate 40, fig. 27.
Nos. 63 – 66 in Cabinet.

Divarication of the lateral toes, 60°; of the inner and middle toes, 35°; of the middle and outer toes, 25°. Length of the middle toe, 13 inches; of the inner toe, 9.75 inches; of the outer toe, 10.25 inches; of the heel, 10 inches; of the foot, 23 to 25 inches; of the step, 40 to 72 inches; of the middle toe beyond the lateral

ones, 4.5 inches. Width of the foot where the toes are articulated to the heel, 1.5 inch; of the heel in its widest part, 8 inches. Distance between the tips of the lateral toes, 9.5 inches; between the inner and middle toes, 6.7 inches; between the tips of the middle and outer toes, 6.3 inches. Versed sine of inward curvature in the middle toe, 0.7 inch; in the inner toe, 0.5 inch. Track shown, of the natural size, on Plate 5, fig. 1.

Remarks. — The only locality with which I am acquainted, of the tracks of this remarkable species, is at the Horse Race in Gill, whence I have obtained only one well-characterized specimen. But I measured its dimensions from several specimens in the rock there, so as to feel confident that I have not overrated them; and yet they are of a very extraordinary character. The animal, however, could not have been as large as the *Brontozoum giganteum*, already described, or the *Otozoum Moodii*, yet to be described.

Species 2. STEROPEZOUM ELEGANS. (Pl. V. Fig. 2.)

Ornithichnites diversus, Am. Jour. Science, Vol. XXIX. fig. 22.
Ornithoidichnites elegans, Mass. Geol. Report, Plate 41, fig. 28.
Nos. 67, 68, 70 – 72, in Cabinet.

Divarication of the lateral toes, 60° to 65°; of the inner and middle toes, 35°; of the middle and outer toes, 30°. Length of the middle toe, 4.4 inches; of the inner toe, 2.3 inches; of the outer toe, 2.8 inches; of the heel, 2.2 inches; of the foot, 6 to 7 inches; of the step, 12 to 21 inches; of the middle toe beyond the lateral ones, 2.4 inches. Width of the foot at the roots of the toes, 1 inch; of the heel, 2 inches. Distance between the tips of the lateral toes, 3 inches; between the inner and middle toes, 2.8 to 3.1 inches; between the middle and outer toe, 2.4 to 2.8 inches. Versed sine of inward curvature in the inner toe, 0.15 inch; of the

middle toe, 0.35 inch ; of the outer toe, outward, 0.2 inch. Track shown, of the natural size, on Plate 5, fig. 2.

Localities.—Marsh's Quarry, Montague ; north part of Montague ; two miles south of Turner's Falls ; and Horse Race, Gill.

Species 3. STEROPEZOUM ELEGANTIUS. (Pl. V. Fig. 3.)

Ornithoidichnites elegantior, Mass. Geol. Rep., Plate 42, fig. 30.

Ornithichnites diversus, *β. platydactylus*, Am. Jour. Sci., Vol. XXIX. p. 319.

Nos. 74–76, 79, in Cabinet.

Divarication of the lateral toes, 70° ; of the inner and middle toes, 30° ; of the middle and outer toes, 40°. Length of the middle toe, 2 inches ; of the inner toe, 1.1 inch ; of the outer toe, 1.3 inch ; of the heel, 1 inch ; of the foot, 7 inches ; of the step, 5.5 inches to 9 inches ; of the middle toe beyond the others, 1.2 inch. Distance between the tips of the lateral toes, 1.5 inch ; between the outer and middle toes, 1.4 inch ; between the inner and middle toes, 1.4 inch. Width of the foot at the roots of the toes, 0.4 inch. Track shown, of the natural size, on Plate 5, fig. 3.

Localities. — Montague, Marsh's Quarry ; Horse Race, Gill ; and South Hadley.

Remarks. — I acknowledge it to be quite possible that the tracks of this species may have been made by the young of *S. elegans.* Yet the table of ratios annexed to this group will show quite a difference, in some respects, between them, besides their size.

Genus II. ARGOZOUM.

Digitigrade, sometimes nearly plantigrade, tridigitate. Toes curved ; the lateral ones mostly outwards, somewhat keel-shaped ; leptodactylous ; vertebrated.

Remarks. — I acknowledge it to be possible that a distinct heel may belong to this genus, although my specimens do not show it. In that case, the first species, *A. Redfieldianum,* would not differ enough from the *Steropezoum ingens* to be separated from it, although some of its characters do not well agree with that species. But as I have seen quite a number of specimens of the tracks of most of the species of this genus, and no very distinct heel is visible, although some of the impressions are quite deep, I group them under a distinct genus; and if that should fail, yet all the species will maintain their ground as distinct species of *Steropezoum,* except the first.

Species I. Argozoum Redfieldianum. (Pl. VI. Fig. 1.)

Ornithoidichnites Redfieldii, Am. Jour. Science, Vol. XLVII., Plate 3, fig. 1.

Nos. 145, 146, 149, in Cabinet.

Divarication of the lateral toes, 75°; of the inner and middle toes, 30°; of the middle and outer toes, 45°. Length of the middle toe, 12 inches; of the inner toe, 8 inches; of the outer toe, 9.5 inches; of the claw, 2 inches; of the foot, 12.5 inches; of the step, 30 inches. Distance between the tips of the lateral toes, 12 inches; between the inner and middle toes, 7.8 inches; between the middle and outer toes, 9 inches. Length of the middle toe beyond the others, 6 inches. Versed sine of the inward curvature of the middle toe, 0.7 inch. Track shown, of the natural size, on Plate 6, fig. 1.

Locality. — Chicopee Falls, on hard, quartzose, and sometimes calcareous, gray sandstone.

Dedicated to my friend, William C. Redfield, Esq., of New

York, whose labors in geology, as well as in meteorology, have inspired the highest respect.

Remarks. — This is the only leptodactylous species on whose tracks I have been able to discover a claw, though I cannot doubt its existence on them all; but it did not make an impression on the mud distinct from the toe. In the present species it is only the claw, and not the phalangeal impressions, that are exhibited, although these also were probably made, but were too slight to be retained.

This, also, is the only species with whose tracks I have discovered coprolites. At Chicopee Falls, where alone this species has been found, I have obtained several specimens of these bodies. These have been analyzed by Dr. S. L. Dana, as already stated; and the results afford one of the most curious examples of the application of chemistry to geology which the records of those sciences contain.

Species 2. ARGOZOUM DISPARI-DIGITATUM. (Pl. VI. Fig. 3.)

Ornithoidichnites macrodactylus, Mass. Geol. Report, Plate 43, fig. 35.

Nos. 69, 73, 91 – 94, in Cabinet.

Divarication of the lateral toes, 40° to 55°; of the inner and middle toes, 18° to 30°; of the middle and outer toes, 20° to 25°. Length of the middle toe, 5.3 inches; of the inner toe, 2.8 inches; of the outer toe, 3.2 inches; of the foot, 5 to 6 inches; of the step, 15 inches. Distance between the tips of the lateral toes, 2.2 to 3 inches; between the inner and middle toes, 2.1 to 2.8 inches; between the outer and middle toes, 2 to 3.4 inches. Projection of the middle toe beyond the others, 1.3 to 2.4 inches. Angle be-

tween the axis of the foot and the line of direction, 0°. Distance of the heel from do., 0.5 inch. Track shown, of the natural size, on Plate 6, fig. 3.

Localities. — Wethersfield and Chicopee Falls.

Species 3. ARGOZOUM PARI-DIGITATUM. (Pl. VI. Fig. 4, 5.)

Ornithichnites minimus, Am. Jour. Science, Vol. XXIX.

Ornithoidichnites isodactylus, Mass. Geol. Report, Plate 45, figs. 38, 39.

Nos. 98 – 100, 229, in Cabinet.

Divarication of the lateral toes, 80° to 90°; of the inner and middle toes, 40°; of the middle and outer toes, 40° to 50°. Length of the middle toe, 1.5 to 1.8 inch; of the inner toe, 1.1 to 1.3 inch; of the outer toe, 1.1 to 1.3 inch. Length of the foot, 1.5 to 2 inches; of the step, 10 to 12 inches (?); of the middle toe beyond the others, 0.7 to 0.9 inch. Distance between the tips of the lateral toes, 1.8 inch; between the inner and middle toes, 1.1 inch; between the outer and middle toes, 1.4 inch. Toes nearly straight. Angle between the axis of the foot and the line of direction, 20°. Track shown, of the natural size, on Plate 6, figs. 4 and 5; the latter, perhaps, a little distorted.

Localities. — Horse Race and Turner's Falls in Gill, and Wethersfield.

Species 4. ARGOZOUM MINIMUM. (Pl. VI. Fig. 6.)

Ornithoidichnites minimus, Mass. Geol. Report, Plate 15, fig. 41.

Nos. 85 and 106, in Cabinet.

Divarication of the lateral toes, 90°; of the inner and middle toes, 50°; of the outer and middle toes, 40°. Length of the middle toe, 0.85 inch; of the inner toe, 0.6 inch; of the outer toe,

0.7 inch. Length of the foot, 0.9 inch; of the step, 3.2 inches; of the middle toe beyond the others, 0.35 inch. Distance between the tips of the lateral toes, 1 to 1.2 inch; between the inner and middle toes, 0.6 to 0.7 inch; between the outer and middle toes, 0.6 to 0.7 inch. Angle between the axis of the foot and the line of direction, 10°. Track shown, of the natural size, on Plate 6, fig. 6.

Locality. — Wethersfield, at the Cove; on red shale.

Remarks. — Since the discovery of the *Macropterna rhynchosauroidea*, I have been in considerable doubt whether the above species should not be referred to it. Certainly the two have been confounded. But I have a few specimens of the *Argozoum minimum* quite distinct, which, as yet, I cannot regard as a Macropterna, and therefore shall let this species remain for the present.

Genus V. PLATYPTERNA.

Heel very broad, as well as the foot at the roots of the toes. Toes slender; for the most part curved. Feet plantigrade.

Remarks. — This elegant genus is distinguished by the unusual breadth of the posterior part of the foot, including the heel; and yet, on many specimens of its tracks, there is no appearance of a heel. It is wanting, also, in the curved or angular space between the toes and the heel which belongs to the genus *Steropezoum*. In most of the specimens, the impression of the heel is rounded posteriorly; but in the *P. tenuis* the heel disappears so gradually, by an upward slope of the foot, that its exact termination on the stone is marked with difficulty. The first species may be only the *Ornithopus gallinaceus*, wanting in the hind toe, and were not some of my specimens of *O. gallinaceus* deeply impressed upon the stone, I should be led to conclude them identical.

Species 1. Platypterna Deaniana. (Pl. VII. Fig. 1.)

Ornithoidichnites Deanii, Mass. Geol. Report, Plate 42, figs. 31, 32, and Plate 44, fig. 37.

Nos. 78 – 83, 96, in Cabinet.

Divarication of the lateral toes, 70° ; of the inner and middle toes, 45° ; of the middle and outer toes, 25°. Length of the middle toe, 3 inches ; of the inner toe, 1.5 inch ; of the outer toe, 1.8 inch ; of the heel, 1.1 to 1.2 inch ; of the foot, 4 to 4.5 inches ; of the step, 9 to 12 inches ; of the middle toe beyond the rest, 1.8 inch. Width of the heel, 0.9 to 1.2 inch ; at the place of insertion of the toes, 1 inch. Distance between the tips of the lateral toes, 2 to 2.5 inches ; between the inner and middle toes, 2.1 to 2.15 inches ; between the outer and middle toes, 2 to 2.35 inches. Versed sine of the curvature of the inner toe, inwards, 0.17 inch ; of the middle toe, inwards, 0.12 inch ; of the outer toe, outwards, 0.22 inch. Track shown, of the natural size, on Plate 7, fig. 1.

Locality. — Wethersfield, at the Cove ; on red shale.

This species is dedicated to Dr. James Deane, of Greenfield, who first called my attention to the subject of footmarks, and who subsequently investigated it with much success.

Species 2. Platypterna tenuis. (Pl. VII. Fig. 2, 3.)

Ornithoidichnites tenuis, Mass. Geol. Report, Plate 43, figs. 33, 34.

Nos. 84 – 87, 208, in Cabinet.

Divarication of the lateral toes, 45° to 60° ; of the inner and middle toes, 20° to 30° ; of the middle and outer toes, 25° to 30°. Length of the middle toe, 2 inches ; of the inner toe, 1 inch ; of the outer toe, 1.3 inch ; of the heel, 0.6 inch ; of the foot, 2.1 to 2.7 inches ; of the step, 7 (?) inches. Width of the heel, 0.6 inch.

Distance between the tips of the lateral toes, 1.1 to 1.7 inch; between the inner and middle toes, 1.1 to 1.4 inch; between the outer and middle toes, 1 to 1.4 inch. Length of the middle toe beyond the others, 0.9 to 1.1 inch. Track shown, of the natural size, on Plate 7, figs. 2 and 3; there being a slight difference between them.

Locality. — Wethersfield, at the Cove; on red shale.

Species 3. Platypterna delicatula. (Pl. VII. Fig. 4.)

Ornithoidichnites delicatulus, Mass. Geol. Report, Plate 45, fig. 40.

Nos. 103, 104, in Cabinet.

Divarication of the lateral toes, 40°; of the inner and middle toes, 22°; of the middle and outer toes, 18°. Length of the middle toe, 1.1 inch; of the inner toe, 0.65 inch; of the outer toe, 0.75 inch; of the heel, 0.4 inch; of the foot, 1.5 inch; of the step, 3 inches; of the middle toe beyond the rest, 0.5 inch. Width of the heel, 0.35 inch; of the foot at the roots of the toes, 0.25 inch. Distance between the tips of the lateral toes, 0.6 inch; between the inner and middle toes, 0.6 inch; between the outer and middle toes, 0.55 inch. Toes slightly curved. Track shown, of the natural size, on Plate 7, fig. 4.

Locality. — Wethersfield, at the Cove; on red shale.

Affinities of the Group. — The biped character of the animals and their tridactyle feet would seem, were we to judge by living animals, to ally them to birds; while the deficiency of the hind toe would lead us to regard most of them as Grallatores. The inference of Dr. Dana, also, from the coprolites of one species, is that they were dropped by such omnivorous birds as those which produce the guano. I shall show in this paper, however, that biped

batrachians once lived, as well as tridactyle quadrupeds, — tridactyle at least on the fore foot.

Table of the Ratio between the several Characters of Group II., *on a Scale of* 100.

	Divarication of			Length of							Distance between			Versed sine of			Width of		
	The lateral toes.	The inner and middle.	The middle and outer.	The inner toe.	The middle toe.	The outer toe.	The foot.	The step.	Middle toe beyond the rest.	The heel.	The tips of the lateral toes.	The inner and middle.	The outer and middle.	The inner toe.	The middle toe.	The outer toe.	The heel.	The foot at the roots of the toes.	Ratio between the length of the foot and the step.
Steropezoum ingens	67	70	56	100	100	100	100	100	75	100	80	81	70	100	100		100	100	2.3
" elegans	70	70	67	24	34	27	27	21	40	22	25	36	29	30	50	50	25	67	2.5
" elegantius	78	60	90	11	15	13	10	11	20		12	18	15					27	2.2
Argozoum Redfieldianum	84	60	100	82	92	93	52	54	100		100	100	100		100				2.4
" dispari-digitatum	53	48	49	29	41	31	23	27	30		22	28	30						2.5
" pari-digitatum	94	80	100	12	13	12	7	20	12		15	14	15						5.5(?)
" minimum	100	100	90	6	9	6	4	6	6		9	8	8						3.5
Platypterna Deaniana	78	90	56	15	23	17	19	19	30	12	18	27	24	34	10	55	11	67	2.5
" tenuis	59	50	60	10	15	13	10	12	16	6	12	17	13				8	40	2.9
" delicatula	44	45	40	7	8	7	6	5	8	4	5	8	6				4	17	2.0

Group III.

Toes four; three pointing forward; the hind toe lying on the inside of the foot and on a prolongation backward of the outer toe.

Genus VI. ORNITHOPUS.

Characters the same as for the Group.

Species 1. Ornithopus Adamsanus. (Pl. VII. Fig. 5.)

Ornithoidichnites Danæ, Am. Jour. Science, Vol. XLVII., Plate 4, fig. 5.

No. 125 in Cabinet.

Divarication of the lateral toes, 100°; of the inner and middle toes, 40°; of the middle and outer toes, 60°; of the middle and hind toes, 140°. Length of the middle toe, 6.5 inches; of the

inner toe, 4.2 inches; of the outer toe, 5.2 inches; of the hind toe, 3 inches. Length of the heel, 6 inches (?). Width of the heel, 3.5 inches; of the foot at the roots of the toes, 2.2 inches. Length of the middle toe beyond the others, 4.3 inches. Distance between the tips of the lateral toes, 7 inches; between the inner and middle toes, 4.5 inches; between the outer and middle toes, 6.5 inches; between the middle and hind toes, 11 inches. Track shown, of the natural size, on Plate 7, fig. 5.

Locality. — Montague City, a few rods east of the canal, on the road to Boston.

Remark. — This is a somewhat doubtful species. The single specimen obtained I could not refer to any known species, and therefore have dedicated it to Professor C. B. Adams, of Amherst College. The hind toe is not very distinct. The heel, or rather the tarsal bone, seems to have sloped upwards at a small angle.

Species 2. ORNITHOPUS GALLINACEUS. (Pl. VIII. Fig. 1.)

Ornithoidichnites tetradactylus, Mass. Geol. Report, Plate 46, fig. 42.

Nos. 112 – 117, 172, 174, in Cabinet.

Divarication of the lateral toes, 60° to 80°; of the inner and middle toes, 35°; of the middle and outer toes, 45°; of the middle and hind toes, 140°. Length of the middle toe, 2.75 inches; of the inner toe, 1.5 inch; of the outer toe, 1.8 inch; of the hind toe, 1.3 inch; of the foot, exclusive of the hind toe, 2.5 to 3 inches; of the step, 7 inches; of the middle toe beyond the others, 1.5 inch. Distance between the tips of the lateral toes, 2.37 inches; between the inner and middle toes, 1.9 inch; between the outer and middle toes, 1.8 inch; between the middle and hind toes, 4.2 inches. Foot plantigrade. Toes nearly straight. Track shown, of the natural size, on Plate 8, fig. 1.

Localities. — Horse Race, Gill; Chicopee Falls; and Wethersfield, at the Cove.

Remarks. — By comparing Plate 7, fig. 1, with Plate 17, fig. 4, leaving out the hind toe of the latter, the force of the remark already made, that the *Platypterna Deaniana* may be only the *Ornithopus gallinaceus* divested of the hind toe, will be appreciated. And we know that the hind toe frequently disappears.

Species 3. ORNITHOPUS GRACILIOR. (Pl. VIII. Fig. 2.)

Ornithoidichnites gracilior, Mass. Geol. Rep., Plate 46, fig. 43.

Nos. 118, 119, 208, in Cabinet.

Divarication of the lateral toes, 75° to 90°; of the inner and middle toes, 40°; of the outer and middle toes, 35° to 50°; of the middle and hind toes, 110° to 130°. Length of the middle toe, 1.5 inch; of the inner toe, 1.1 inch; of the outer toe, 1.1 inch. Hind toe digitigrade, articulated high upon the tarsus; length of the same from the roots of the toes, 0.8 inch; of the part that impresses the ground in walking, 0.3 to 0.5 inch. Middle toe rather keel-shaped. Toes nearly straight. Length of the foot, excluding the hind toe, 1.4 to 1.7 inch; of the middle toe beyond the rest, 0.7 inch. Distance between the tips of the lateral toes, 1.7 inch; between the inner and middle toes, 1.05 inch; between the middle and outer toes, 1.3 inch; between the middle and hind toes, 2 inches. Track shown, of the natural size, on Plate 8, fig. 2.

Locality. — Wethersfield.

Species 4. ORNITHOPUS LORIPES. (Pl. VIII. Fig. 3.)

Ornithoidichnites divaricatus, Mass. Geol. Rep., Plate 44, fig. 36.

Nos. 95, 97, 101, 102, 121, 143, in Cabinet.

Divarication of the lateral toes, 100°; of the inner and middle toes, 50°; of the middle and outer toes, 50°; of the middle and hind toe, 120°. Length of the middle toe, 5 inches; of the inner toe, 3.75 inches; of the outer toe, 4 inches; of the foot, 6.5 to 7 inches; of the heel, 2 inches; of the hind toe, 2.75 inches; of the step, 16 to 23 inches; of the middle toe beyond the rest, 2.5 inches. Distance between the tips of the lateral toes, 5.7 inches; between the inner and middle toes, 3.9 inches; between the middle and outer toes, 3.9 inches; between the middle and hind toes, 6.8 inches. Versed sine of the backward curvature of the hind toe, 0.2 inch; of the inward curvature of the inner toe, 0.4 inch; of the same in the middle toe, 0.6 inch; of the same in the outer toe, 0.2 inch. Angle between the axis of the foot and the line of direction, 10° inwards. Distance of the middle of the heel from the line of direction, 3 inches. Track shown, of the natural size, on Plate 8, fig. 3.

Localities.—Horse Race, southwest part of Montague; Chicopee Falls; Cabotville; Northampton; Wethersfield.

Remarks.—I am so well satisfied that the track which I described in the Massachusetts Geological Report as the *Ornithoidichnites divaricatus*, having only three toes, is the same as that made by the *Ornithopus loripes*, that I have united them. For when the fourth toe is left out of the account, they do not seem distinct; and that toe, so frequently wanting, I do not regard as sufficient to characterize a species.

Plate 24, fig. 4, is copied and reduced from a specimen in my cabinet obtained at Marsh's Quarry in Montague. It will give a good idea of the relative situation of the feet when the animal walked.

Species 5. ORNITHOPUS RECTUS. (Pl. V. Fig. 4.)

Nos. 244, 245, in Cabinet.

Divarication of the front lateral toes, 75° to 80°; of the inner and middle toes, 40° ; of the middle and outer toes, 40° ; of the inner and hind toes, 40° to 60°. Length of the hind toe, 1.8 inch ; of the inner front toe, 2.7 inches; of the middle front toe, 3.5 inches ; of the outer toe, 2.9 inches; of the middle toe beyond the rest, 1.4 inch ; of the foot, 4.5 inches ; of the step, 18 inches. Heel rather broad, and extending back farther than the hind toe. Distance between the tips of the hind toe and the middle front toe, 4 inches ; between the second and middle toes, 2.2 inches ; between the middle and outer toes, 2.4 inches ; between the second and outer toes, 3.6 inches ; between the rows of tracks, 7 inches. Axis of the foot nearly coincident with the line of direction. Track shown, of the natural size, on Plate 5, fig. 4.

Locality. — Horse Race, Gill ; at the quarry, three miles above Turner's Falls ; on gray micaceous sandstone.

Remarks. — This species was discovered while this paper was passing through the press. The quite distinct specimens on which it is founded were presented to me by Mr. Ptolemy P. Severance, who has charge of the quarries and public works at Turner's Falls. I was in doubt whether to refer this species to *Ornithopus* or *Plectropus ;* but the shortness of the heel and the nearness of the roots of the hind toe to the roots of the others have led me to place it as a fifth species of the former. In the great distance between the tracks of the right and left foot, it differs from all other species except the *Harpedactylus concameratus ;* and one cannot but inquire whether possibly the animal was not a quadruped, moving forward like the Proteus, as described in another part of this paper. At present, however, the evidence is very slight of a quadrupedal char-

acter in this animal. The hind toe, it will be seen, stands at nearly right angles to the axis of the foot; not on a posterior prolongation of the outer front toe, as is usual in four-toed living birds, and in most species of *Ornithopus*.

Affinities of the Group. — The same characters which ally the last group to birds exist in this also. We have, in addition, a hind toe, situated as in many of the four-toed birds; so that its impression on mud lies on a posterior prolongation of the outer toe. Furthermore, in one species at least (the *O. gracilior*), we have proof that the hind toe was articulated high upon the tarsus, so that only its extremity reached the ground, as is the fact with many birds. So that, in the present group, the relations to birds are stronger than in any of the other leptodactylous species. We have proof that some fossil animals, with tridactylous feet, were quadrupeds, and probably some bipeds were batrachians; but I know of no example in living or fossil nature in which a biped with four toes, situated as in this group, was any thing else than a bird.

Table of the Ratio between the several Characters of this Group, on a Scale of 100.

	Divarication of				Length of								Distance between				Versed sine of the curve			Width of		Ratio between the length of the foot and the step.
	The lateral toes.	The inner and middle	The outer and middle.	The middle and hind.	The inner toe.	The middle toe.	The outer toe.	The hind toe.	The foot.	The step.	Middle toe beyond the rest.	The heel.	The tips of the lateral toes.	The inner and middle.	The outer and middle.	The middle and hind.	Of the inner toe.	Of the middle toe.	Of the outer toe.	The heel.	The foot at the roots of the toes.	
Ornithopus Adamsanus	100	80	100	100	100	100	100	100			100	100	100	100	100	100	0	0	0	100	100	
" gallinaceus	76	70	75	100	36	42	35	43	41	36	33		34	42	28	38	0	0	0		23	2.5
" gracilior	82	80	71	86	26	23	21	27	24		15		24	23	20	18	0	0	0			
" loripes	100	100	82	86	89	77	77	92	100	100	56	33	81	87	60	62	100	100	100	43	68	2.9
" rectus	77	57	83	75	64	54	56	60	82	90	42		50	55	43						44	4.0

GROUP IV.

Feet tetradactylous, plantigrade; three of the toes directed forward, and the fourth situated far back on the heel, making various angles with the axis of the foot. Heel large or long, consisting sometimes of the whole tarsus.

Genus VII. POLEMARCHUS.

Heel very large and rounded, making an impression as deep as the toes. Three slender toes directed forward; the hind toe situated far back on the heel, and at right angles to the axis of the foot.

Species 1. POLEMARCHUS GIGAS. (Pl. IX. Fig. 1.)

Sauroidichnites polemarchius, Mass. Geol. Report, Plate 35, fig. 17.

Nos. 34 – 36, in Cabinet.

Divarication of the lateral toes, 45°; of the inner and middle toes, 20°; of the middle and outer toes, 25°; of the middle and fourth toes, 80°. Length of the middle toe, 11.2 inches; of the inner toe, 8.5 inches; of the outer toe, 8.3 inches; of the hind toe, 2.5 inches; of the heel, 3.8 inches; of the middle toe beyond the rest, 3.2 inches; of the foot, 15 inches; of the step, 48 inches. Width of the heel, 3.9 inches; of the foot at the roots of the toes, 2.5 inches. Distance between the tips of the lateral toes, 6.6 to 8.7 inches; between the inner and middle toes, 4 to 4.6 inches; between the middle and outer toes, 5.5 to 7.5 inches; between the middle and hind toe, 13 inches. Fourth toe straight. Versed sine of the inward curvature of the inner toe, 0.45 inch; of the inward curvature of the middle toe, 0.9 inch; of the inward curva-

ture of the outer toe, 0.3 inch. Foot plantigrade. Toes very slender. Track shown, of the natural size, on Plate 9, fig. 1.

Localities. — Chicopee Falls, in the bed of the river; and at a quarry one mile south of Cabotville.

Remark. — I have not met with a sufficient number of these tracks in place to be sure that they were not made by a quadruped.

Genus VIII. PLECTROPUS.

Heel elongated, apparently extending to the tarsal joint, quite narrow, making an impression as deep as the toes with its anterior part. Fourth toe proceeding at right angles from the heel behind the roots of the toes, resembling the spur on some of the gallinaceous birds.

Species 1. Plectropus minitans. (Pl. IX. Figs. 2, 3.)

Sauroidichnites minitans, Mass. Geol. Report, Plate 33, fig. 11.

Nos. 17 – 23, 153, in Cabinet.

Divarication of the lateral toes, 87° to 95°; of the inner and middle toes, 37° to 42°; of the middle and outer toes, 45° to 60°; of the middle and hind toes, 90° to 110°. Length of the middle toe, 2.5 to 3.8 inches; of the inner toe, 1.7 to 2.6 inches; of the outer toe, 1.8 to 2.5 inches; of the hind toe, 0.9 inch; of the heel, 1 to 2 inches; of the foot, 3.5 to 6 inches; of the step, 15 to 17 inches. Width of the heel, 0.4 to 0.5 inch; of the foot at the roots of the front toes, 0.4 inch. Distance between the tips of the lateral toes, 2.7 to 3.7 inches; between the inner and middle toes, 1.6 to 2.6 inches; between the outer and middle toes, 2.4 to 2.9 inches; between the middle and hind toes, 3.3 to 4.8 inches. Length of the middle toe beyond the rest, 1.5 to 2 inches. Versed sine of the inward curvature of the middle toe, 0.15 inch; of the outward curva-

ture of the outer toe, 0.1 inch. Heel sloping upwards posteriorly, in a gradual manner, so as to leave an impression on the mud a greater or less distance. Feet for the most part plantigrade. Distance between the roots of the three forward toes and the hind toe, 0.7 to 0.9 inch. Track shown, of the natural size, on Plate 9, figs. 2, 3.

Localities. — Chicopee Falls, one mile south of Cabotville; and at Wethersfield.

Remarks. — The singular manner in which the hind toe on the track of this and the following species, from being on the upper layer at right angles with the heel, changes in passing downwards, so as to correspond almost with that of *Ornithopus gallinaceus*, has been already noticed in describing the tenth general character. This fact shows us that little dependence can be placed upon this character; and it approximates two species of tracks, which, at first view, seem very much unlike, namely, *Ornithopus gallinaceus* and *Plectropus minitans.*

Species 2. PLECTROPUS LONGIPES. (Pl. VIII. Fig. 4; Pl. X. Fig. 1–3.)

Sauroidichnites minitans, Mass. Geol. Rep., Plate 33, fig. 12.

Nos. 24 – 26, 154, 155, 163, 164, 171, in Cabinet.

Divarication of the lateral toes, 70° to 75°; of the inner and middle toes, 30° to 37°; of the middle and outer toes, 40° to 45°; of the middle and hind toes, 90° to 100°. Length of the middle toe, 2.1 to 3.5 inches; of the inner toe, 1.4 to 2 inches; of the outer toe, 1.7 to 2.5 inches; of the hind toe, 0.6 to 1 inch; of the heel, 2.6 to 5.7 inches; of the foot, 6 to 9 inches; of the step, 14 to 17 inches. Width of the heel, 0.3 inch; of the foot at the roots of the front toes, 0.4 inch. Distance between the tips of the lateral toes, 2.2 to 2.6 inches; between the inner and middle toes, 1.4 to 1.9 inch; between the outer and middle toes, 1.6 to

2.3 inches; between the middle and hind toes, 3.3 to 4.7 inches. Distance between the roots of the front toes and the root of the hind toe, 0.8 to 1.3 inch. Length of the middle toe beyond the rest, 1 to 1.6 inch. Toes slightly curved; the two front inner ones inward, and the outer one outward. Axis of the foot corresponding nearly with the line of direction. The whole length of the tarsal bone reaches the ground usually in walking. Track shown, of the natural size, on Plate 8, fig. 4, and Plate 10, figs. 1, 2, 3.

Localities. — Wethersfield, at the Cove, on gray shale, or micaceous sandstone, at Turner's Falls, and Cabotville.

Remarks. — Nearly all the facts within my reach would indicate that this animal was a biped. Yet the long heel and side toe, so like a lacertilian, have long led me to suspect it might be a quadruped. I have sometimes found two tracks almost in the same spot, as is common with quadrupeds. But still the most instructive case of this kind, already referred to under the third general character, does not confirm this supposition. By a careful dissection of No. 171 in my cabinet, I found, on three successive layers of the rock, three impressions so unlike as to perplex the most practised eye; but I think I now understand them. The uppermost layer presents a track as exhibited on Plate 10, fig. 1, having five toes in front and one articulated to the tarsus, or tarso-metatarsus. The lowest layer, represented on Plate 10, fig. 3, shows five toes most symmetrically arranged, and scarcely exciting a suspicion that there could be two tracks. But I felt quite confident that existing animals would not allow us to give six toes to the foot of any biped or quadruped; and therefore I ventured, at the risk of spoiling the specimen, to cleave it asunder once more; when I was presented with the outline shown on Plate 10, fig. 2, which seems to me to solve the enigma to a considerable extent. It shows, in my

opinion, the impression of two feet nearly in the same spot; one of them a right foot, and the other a left. If they were those of a quadruped, however, they ought to be both right or both left. I regard the toes *a*, *b*, *c*, as belonging to the fore foot, and *d* as its fourth or lateral toe; while *e*, *f*, *g*, are the three front toes of the hind foot, and *h* is its hind toe, which, on this layer, is much more oblique to the heel than on the upper layer, Plate 10, fig. 1, as I have observed to be the case in other instances, and which I impute to a slight onward movement in the mud, as the track was filled up. I at first regarded this specimen as a distinct species from the *P. longipes*. But the resemblance is too close between them to allow of a separation. The dimensions of the two tracks on Plate 10, fig. 2, are, however, considerably different, as the following statement of their dimensions will show: —

Fore foot. — Divarication of the lateral toes, 75°; of the inner and middle toes, 35°; of the outer and middle toes, 40°; of the middle and hind toes, 70°. Length of the middle toe, 2.8 inches; of the inner toe, 1.6 inch; of the outer toe, 1.8 inch; of the hind toe, 1 inch. Distance between the tips of the lateral toes, 2.4 inches; between the inner and middle toes, 1.8 inch; between the outer and middle toes, 2.1 inches; between the middle and hind toes, 3.5 inches. Length of the middle toe beyond the rest, 1.6 inch. Toes somewhat bent.

Hind foot. — Divarication of the lateral toes, 80°; of the inner and middle toes, 40°; of the outer and middle toes, 40°; of the middle and hind toes, 115°. Length of the middle toe, 2.2 inches; of the inner toe, 1.5 inch; of the outer toe, 1.7 inch; of the hind toe, 0.7 inch. Distance between the tips of the lateral toes, 2.2 inches; between the inner and middle toes, 1.4 inch; between the

outer and middle toes, 1.6 inch; between the middle and hind toes, 3.3 inches. Toes slightly curved.

It is clear, I think, from the angles of divarication of the forward toes, as well as from the length of the toes and the position of the lateral or hind toes, that the front track of this specimen must have been made by a left foot, and the other by a right foot; although I feel a little doubt whether the toe *d* is the hind toe of the fore foot, as it only shows its extremity. The hind foot, as appears from the above measurements, is smaller than the fore foot; which is not usual in batrachians or lacertilians. Upon the whole, I cannot make out this track to be of quadrupedal origin, and yet its general character is such as to leave me still in doubt whether the animal was not a quadruped.

One other specimen of the tracks of this species (No. 163 of Cabinet), split twice asunder, shows the forms delineated on Plate 15, figs. 17–19. Here it is not obvious that two tracks are united. Indeed, had not the case above given furnished the clew, we should not suspect from this specimen that more than one track existed. The occurrence of two specimens of these double tracks strengthens the suspicion, that the animal that made them (*Plectropus longipes*) was a quadruped.

Genus IX. TRIÆNOPUS.

Feet tridactyle in front, plantigrade; divarication small: toes very slender; hind toe proceeding from the extremity, or near the extremity, of the heel. Heel very slender. Gregarious.

Remark. — The distinction between this and the preceding genus is not striking, and perhaps not permanent. It consists in the much more slender and delicate character of the whole foot, and in the position of the fourth toe. But I have some reason to suspect

that the species of *Triænopus* may be quadrupeds, or rather that there is but one species of this genus, and that a quadruped, with feet quite unlike. For, in several cases, I find two tracks occupying almost exactly the same place, and pointing in the same direction, as has been shown in the case of *Plectropus longipes.* But the tracks of *Triænopus* are extremely crowded together; and although more perfect than any others I have ever found, yet I have not been able to trace out consecutive tracks. So brittle is the beautiful red shale on which they are imprinted, that it is rare to be able to obtain specimens more than a foot square.

Species 1. TRIÆNOPUS BAILEYANUS. (Pl. X. Fig. 4.)

Sauroidichnites Baileyi, Mass. Geol. Report, Plate 32, figs. 8, 9.

Nos. 13–16, 161, 162, 165, 166, 168, 169, 175, 178, 179, 212, in Cabinet.

Divarication of the lateral toes, 35° to 40°; of the inner and middle toes, 15° to 20°; of the middle and outer toes, 15° to 20°; of the middle and hind toe, 30° to 40°. Length of the middle toe, 2.5 to 3.3 inches; of the inner toe, 1.6 to 2.2 inches; of the outer toe, 2 to 2.5 inches; of the hind toe, 0.7 to 0.9 inch; of the heel, 1.4 to 2 inches; of the foot, 4 to 4.9 inches; of the step, 7 inches (?); of the middle toe beyond the rest, 1.5 inch. Distance between the roots of the forward toes and that of the hind toe, about 1 inch; between the tips of the lateral toes, 1 to 1.8 inch; between the inner and middle toes, 1.1 to 1.6 inch; between the outer and middle toes, 1.3 to 1.7 inch; between the middle and hind toe, 3.2 to 3.7 inches. Extremity of the heel adhering to the mud, so that when the former was lifted up, the latter followed, forming a ridge. Behind this ridge we sometimes find what seems a continuation of the heel backward; or, more probably, a hind toe, sometimes more

than an inch long, shown by dotted lines on Plate 15, figs. 10 and 11. Toes and heel nearly straight and very narrow. Width of the foot at the roots of the toes, 0.3 inch; of the heel, 0.2 inch. Track shown, of the natural size, on Plate 10, fig. 4.

Remarks. — The changes of form in the track of this species on successive layers of rock are instructive, and have already been in part described under the third general character. Plate 15, fig. 10, shows the track on the highest layer of No. 175 (Cabinet); fig. 11 shows the second track, half an inch lower; fig. 12, the third track, one quarter of an inch lower; and fig. 13, the fourth impression, one third of an inch lower. On the upper layers the rock is broken off, so as not to show the extremities of all the toes; but lower down they are all exhibited, both from their becoming shorter, and from the manner in which the mud was silted into the impression, so as not to fill perpendicularly, but obliquely.

The species is dedicated to Professor J. W. Bailey, of West Point, the eminent microscopist.

Plate 19, fig. 6, shows the tracks, on a specimen from Wethersfield (No. 169, Cabinet), of this and the following species, reduced three times from the natural size. They are in relief; and on the other side of the specimen (which is an inch and a half thick), they are much more numerous, so numerous, indeed, that individual tracks can scarcely be traced out. Yet in all these cases, the tracks point nearly in the same direction; as is the case with almost all the specimens from that remarkable locality, which leads to the inference that the animals were gregarious.

Locality. — Wethersfield, at the Cove; on beautiful red shale.

Species 2. TRIÆNOPUS EMMONSIANUS. (Pl. X. Fig. 5.)

Sauroidichnites Emmonsii, Mass. Geol. Report, Plate 31, figs. 5 – 7.

Nos. 7 – 12, 157, 160, 162, 165, 169, 177, in Cabinet.

Divarication of the lateral toes, 50° ; of the inner and middle toes, 25° ; of the middle and outer toes, 25°; of the middle and hind toes, 115°. Hind toe proceeding from the extremity of the heel. Length of the middle toe, 2.3 to 3 inches; of the inner toe, 1.5 to 2 inches; of the outer toe, 1.5 to 2.2 inches; of the hind toe, 0.7 to 1 inch; of the heel, 0.3 to 0.5 inch; of the middle toe beyond the rest, 1.1 inch; of the foot, 2.8 to 3.6 inches. Distance between the tips of the lateral toes, 1.5 to 2 inches; between the inner and middle toes, 1.1 to 1.5 inch; between the middle and outer toes, 1.3 to 2 inches; between the middle and hind toes, 2.9 to 3.9 inches. Heel 0.2 inch wide; at the roots of the front toes, 0.4 inch. Versed sine of the inward curvature of the inner toe, 0.15 inch; of the same in middle toe, 0.1 to 0.15 inch; of outer toe, outwards, 0.05 inch. Track shown, of the natural size, on Plate 10, fig. 5.

Locality.—Wethersfield, at the Cove; on red shale, intermingled with the last species.

This species is dedicated to Professor Ebenezer Emmons, of Albany.

No. 7 (Cabinet) furnishes us with an instructive example of a change of form in the track of this species, as it appears on successive layers of little more than an inch in thickness. Plate 15, fig. 14, shows the track on the uppermost layer; fig. 15, on the second; and fig. 16, on the lowest.

Remarks. — Although my specimens of the tracks of this and the preceding species are more numerous than of any other, and most of them as perfect impressions as can be made on a plastic material, I have not been able to ascertain the length of the step, nor, in fact, to satisfy myself whether the animal was a biped or a

quadruped. The shale on which they occur is so brittle that it is difficult to obtain a slab more than a foot long, and then the tracks are so numerous that their interference obscures the characters. When I first opened the rocks at this spot, ten years ago, these points probably might easily have been settled; but I was not then aware of their importance. I strongly suspect that the tracks of the two species of *Triænopus* may be only those of the hind and fore feet of a lizard. I have several specimens, in which two tracks occur almost in the same place, as already fully described.

Genus X. HARPEDACTYLUS.

Leptodactylous; three to four-toed. Toes all curved inward, like sickles.

Species 1. Harpedactylus gracilis. (Pl. XIV. Fig. 2.)

Sauroidichnites tenuissimus, Mass. Geol. Report, Plate 34, fig. 13.

Nos. 27 – 30, in Cabinet.

Divarication of the outer of the three front toes, 70°; of the inner and middle toes, 33°; of the middle and outer toes, 35°; of the fourth or hind toe and the outer front toe, 55°. Length of the inner front toe, 1.9 inch; of the middle toe, 2.2 inches; of the outer toe, 1.8 inch; of the fourth or hind toe, 0.9 inch; of the heel, 1.6 inch; of the foot, 3.7 inches; of the step, 8 inches; of the middle front toe beyond the rest, 0.8 inch. Distance between the tips of the lateral front toes, 2.2 inches; of the inner and middle toes, 1.25 inch; of the outer and middle toes, 1.5 inch; of the hind and middle toes, 2 inches; between the roots of the front toes and the origin of the fourth toe, 0.7 inch. Width of the heel, 0.2 inch. Tarsal joint lifting up

the mud as the animal walked. Toes all curved inward. Versed sine of the hind toe, 0.12 inch; of the inner front toe, 0.17 inch; of the middle toe, 0.13 inch; of the outer toe, 0.2 inch. Angle between the axis of the foot and the line of direction very large. Axis of the heel prolonged strikes the tip of the outer toe. Middle front toe making an angle with that axis of 40°. Inner toe making a similar angle equal to 70°. Fourth toe making an angle equal to 60°. Toes, particularly the posterior, extremely narrow. Track shown, of the natural size, on Plate 14, fig. 2, copied from a quite perfect specimen in Mr. D. Marsh's cabinet, lately found by him at Turner's Falls. Plate 20, fig. 1, shows two tracks, in their normal position, from the same locality, reduced from their natural size three times.

Localities. — Turner's Falls, Horse Race, and Wethersfield.

Remarks. — Although I described this species in my Report on the Geology of Massachusetts, yet so defective were my specimens, that I despaired of giving it a place in this paper, until the discovery of the specimens from which the preceding figures were drawn. One cannot look at these, without feeling a strong impression that the animal will prove to be a quadruped; and facts which I have yet to mention, as to the small fore feet of some animals having often made only a slight impression on mud, lead to the suspicion that such may be discovered in connection with these. If, indeed, Plate 14, figs. 4 and 5, sketched from a specimen presented to me by Dr. Deane, and found at Turner's Falls, belongs to this species, as I rather presume it may, it shows us the hind and fore feet.

Species 2. HARPEDACTYLUS CONCAMERATUS. (Pl. XIV. Fig. 3.)

No. 180 in Cabinet.

Tridigitate. Divarication of the lateral toes, 60°; of the inner

and middle toes, 25° ; of the outer and middle toes, 35°. Length of the middle toe (measured on the chord), 3.2 inches; of the inner toe, 2 inches; of the outer toe, 1.6 inch; of the middle toe beyond the rest, 2.2 inches. Distance between the tips of the lateral toes, 3.5 inches; between the inner and middle toes, 1.7 inch; between the middle and outer toes, 3.4 inches. Versed sine of the inward curvature of the inner toe, 0.3 inch; of the middle toe, 0.6 inch. Outer toe straight. Width of the curved ridge between the toes and heel (the space between the dotted line and the heel, in Plate 14, fig. 3,), 0.3 to 0.6 inch: the length of the same (which is the width of the foot at the roots of the toes), 2.2 inches. Length of the heel (*breadth* literally), 1.2 inch. Breadth of do., 2 inches. Length of the foot, 4.7 inches; of the step, 8 to 12 inches, if considered a biped. Foot vaulted, so as to leave a ridge between the toes and the heel, and hence the specific name. Axis of the foot very much turned inward towards the line of direction. Distance from that line, 5 inches. Track shown, of the natural size, on Plate 14, fig. 3.

Remarks. — The specimen, Plate 14, fig. 3, from which most of the above description was taken, is a very perfect one, from Turner's Falls, presented to me by Mr. Ptolemy P. Severance. But just as I was sending this paper to the press (April 27th), my attention was called to a slab of ten tracks in a row, or rather two rows, lying in the sidewalk in Greenfield Street, in front of the residence of Franklin Ripley, Esq. It was from the Horse Race, and is a gray micaceous sandstone. I at once recognized these tracks as essentially corresponding with those of the *H. concameratus.* They are distinguished from all others by the axis of the foot turning so much inward toward the line of direction, by the great distance of the middle of the heel from that line (5 inches), and by

the sickle shape of the inner toes especially. One can hardly doubt, on inspecting the specimen sketched on Plate 24, fig. 6, reduced 12 diameters, that the animal was a biped; yet the inquiry arises, whether it may not have been a quadruped with feet placed like those of the Proteus, exhibited on Plate 19, fig. 3. This is possible; but the very nearly exact alternation of the tracks in the two rows seems hardly consistent with such a supposition. If we could discover a small fore-foot with each large one, such an alternation would be natural; but no trace of such tracks can be seen. And, upon the whole, my present conviction is, that we must regard the animal as a biped, with short legs and a wide body, walking much like the common goose. Had I discovered this slab earlier, I should probably have separated this species from *Harpedactylus;* but as the thing now stands, such a change is difficult, and perhaps it is not important. I am glad to be able to give a sketch of the slab in this paper, although the individual tracks are not laid down with quite so much accuracy as I could have wished.

Species 3. Harpedactylus rectus. (Pl. V. Fig. 5.)

Divarication of the lateral toes, 32° to 38°; of the inner and middle toes, 10° to 15°; of the middle and outer toes, 25° to 30°. Length of the inner toe, 2.5 inches; of the middle toe, 3.75 inches; of the outer toe, 2.5 inches; of the middle toe beyond the rest, 1.5 inch; of the foot, 4 inches at least; of the step, 5.5 inches. Heel nearly 2 inches broad; length not determined. Distance between the tips of the inner and middle toes, 1.5 to 2 inches; between the middle and outer toes, 2 to 2.5 inches; between the lateral toes, 2.25 to 3 inches; between the rows of tracks made by the right and left foot, 3.5 inches. Axis of the foot turned inward a few degrees towards the line of direction. Track shown,

of the natural size, on Plate 5, fig. 5 ; and a row of the tracks, reduced to one sixth the natural size, is shown on Plate 24, fig. 7.

Locality. — Turner's Falls, Gill, at the quarry, eighty rods above the cataract.

Remarks. — The specimen from which this species has been described was in the possession of Mr. Ptolemy P. Severance, but what is to be its ultimate destination is not yet known. A sketch of it, accurately reduced, is given on Plate 24, fig. 7. The species is distinguished from all others by the long and delicate toes, in connection with an elliptical heel, whose posterior part is not well marked, but which appears to me to approach nearly to that of *Harpedactylus concameratus;* and therefore I have placed this species under that genus, though the specific name *rectus*, as applied to the toes, seems almost to contradict the generic name. It differs from other species, also, by the toes pointing so much inward towards the line of direction, and also in the shortness of the step compared with the length of the foot, which is more remarkable than in any species hitherto discovered, the ratio between them being only 1.37. Yet the nine steps shown on Plate 24, fig. 7, although somewhat broken, prove conclusively what is the length both of the foot and the step. I have a suspicion that it was a web-footed animal, but no positive evidence. This species was discovered while this paper was passing through the press.

Affinities of the Group. — The probable biped character of most of the species, and the trifid character of the front part of the foot, are presumptions in favor of their being birds. On the other hand, the curved and slender character of most of the toes, the large or long tarsus, forming the heel, and the articulation of the hind toe, when present, so far back upon the tarsus, assimilate them to

lizards; whose feet certainly have a general resemblance to the tracks of these animals. On the other hand, the resemblance between the front part of the foot of the genus *Triænopus* and that of certain birds is very striking, as the sketches on Plate 20, copied from Gray's *Genera of Birds*, subfamily Columbinæ, will show. Fig. 2 represents the foot of the *Lopholaimus antarcticus;* figs. 3 and 4, the feet of *Cathartes fœtens;* and fig. 5, the foot of a species of *Gryphus.* But the fact is, these are birds which for the most part never walk upon the ground, and certainly never upon a muddy shore; so that we may be sure that this accidental resemblance does not indicate any real affinity. Upon the whole, I am more inclined to refer this group to the lacertilian tribe than to birds, although the evidence does not seem very decided.

Table of the Ratio between the several Characters of this Group, on a Scale of 100.

	Divarication of				Length of								Distance between				Versed sine of the curve			Width of		
	The lateral toes.	The inner and middle	The outer and middle	The middle and hind.	The inner toe.	The middle toe.	The outer toe.	The hind toe.	The foot.	The step.	Middle toe beyond the rest.	The heel.	The tips of the lateral toes.	The inner and middle.	The outer and middle.	The middle and hind.	Of the inner toe.	Of the middle toe.	Of the outer toe.	The heel.	The foot at the roots of the toes.	Ratio between the length of the foot and the step.
Polemarchus gigas	49	51	48	70	100	100	100	100	20	100	100	90	100	100	100	100	100	100	100	100	100	3.2
Plectropus minitans	100	100	100	87	31	27	25	36	62	33	56	36	42	49	40	30		17	33	12	16	3.4
" longipes	74	37	81	83	20	25	25	32	100	31	41	100	32	37	29	30				8	16	2.1
Triænopus Baileyanus	40	20	33	31	22	26	26	32	13	14?	47	40	18	32	23	26				4	12	
" Emmonsianus	55	27	48	10	21	24	22	36	43		34	10	24	30	26	26	33	13	16	5	16	

Note. — The three species of *Harpedactylus* are omitted in the above table, because they are so obviously unlike the other species that minute comparisons seem unnecessary.

Appendix to Group IV.

Remarks. — Some general resemblances between the foot of the following genus and those of the preceding genera of this group have led me to place it in an appendix, though very probably it may prove to have very different affinities.

Genus XI. TYPOPUS.

Foot plantigrade, except the middle toe, which is strikingly digitigrade; trifid; toes leptodactylous. Heel a prolongation backward of the outer toe; yet, from the anterior extremity of this, a ridge extends nearly at right angles, which appears to form a basis for the insertion of the other toes.

Remarks. — If I had not very distinct tracks of this species, I should not attempt to describe it, it is so anomalous and unlike existing nature. The lateral character of the heel is one peculiarity. But the ridge on the foot, running obliquely from this to the roots of the inner toe, is more peculiar; seeming, in fact, to be only a curved continuation backward of that toe. I have been, indeed, in doubt whether to consider it as a heel, or that and the toe as one crooked toe. But the middle toe seems to have been articulated to this ridge, though high up, leaving a cavity between. Hence I have, upon the whole, regarded this ridge as a part of the heel. That part of the heel which is a continuation backward of the outer toe might be considered a hind toe, were not its width and bluntness, as seen on the tracks, more characteristic of a heel.

Species 1. Typopus abnormis. (Pl. X. Fig. 6.)

Sauroidichnites abnormis, Am. Jour. Science, Vol. XLVII., Plate 3, figs. 6, 7, 8.

Nos. 131 – 133, in Cabinet.

Divarication of the lateral toes, 35°; of the inner and middle toes, 20°; of the middle and outer toes, 15°. Length of the middle toe, so far as it usually impresses the ground in walking, 1.9 inch; whole length of do., 2.8 inches; of the inner toe, 1.3 inch; of the outer toe, 1.8 inch; of the part of the heel running directly backward, 0.7 inch; of the lateral part, 2 inches; of the foot, 4 inches; of the step, 18 inches; of the middle toe beyond the rest, 1.4 inch. Width of the heel, 0.2 to 0.3 inch; of the foot at the roots of the toes, 2.2 inches. Distance between the tips of the lateral toes, 2.8 inches; between the inner and middle toes, 1.8 inch; between the middle and outer toes, 2 inches. Axis of the left foot turned inward from the line of direction, 15°; of the right foot, 30°. Distance of the axis of the foot from the line of direction, 2.5 inches. Right foot shown, of the natural size, on Plate 10, fig. 6. Plate 19, fig. 7, shows three tracks in their normal position, one sixth of the natural size (linear measure), sketched from a slab in the cabinet of Mr. Dexter Marsh.

Locality. — Turner's Falls.

Plate 15, fig. 2, is copied from a very distinct specimen of footmarks from Wethersfield, and seems to approach the *Typopus* in form, though a distinct species. But I hesitate to describe it as such, because, being near another track, its form may have been altered, and I have only one specimen.

Remarks. — All the specimens yet found show the extraordinary fact, that the right foot has a divergence of 15° more than the other from the line of direction; and especially the specimen in Mr. Marsh's collection, from which Plate 19, fig. 7, was copied. This surely cannot be natural, if the animal was a biped; for nature, with few exceptions, constructs pairs of organs alike. What

improbability is there in the supposition, that the animal which made the tracks at the locality (Turner's Falls) had one of its legs (the right) broken, and that it subsequently united in a wrong position?

Affinities of the Genus. — The biped character of the animal and its trifid toes afford a presumption that it was a bird; yet the great peculiarity of its feet would rather lead us to suspect that it might have been a saurian or batrachian.

GROUP V. BIPEDAL BATRACHIANS?

Toes four, directed forward, or obliquely forward. Bipedal.

Genus XII. OTOZOUM.

Tetradactylous; pachydactylous; *lobopedate;* plantigrade. Toes all directed forward; the inner one shortest; the second next longer; the third longest of all; the fourth but little shorter; all making distinct phalangeal impressions on mud, the inner toe most distinctly; three are made by the inner toe, four by the second, and three by the two outer toes. Two bones of the metacarpus (?), articulated to the phalanges of the two outer toes, make a distinct impression. Cushion beneath the carpus rounded beneath, and sloping upward posteriorly.

Species 1. OTOZOUM MOODII. (Pl. XII. Fig. 1.)

American Journal of Science, Vol. IV., New Series, p. 55.

No. 234, in Cabinet.

Divarication of the outer toes, 35°; of the inner and second toes, 15°; of the outer and third toes, 12°; of the two middle toes, 5°. Length of the inner toe, 8.5 inches; of the second toe,

10.25 inches; of the third toe, 8 inches; of the outer toe, 8.5 inches; of the foot, 20 inches; of the step, about 3 feet. Distance between the extremities of the outer toes, 1.3 inch; of the inner and second toes, 6.5 inches; of the second and third, 3.4 inches; of the third and fourth, 2.7 inches. Width of the toes, 2 to 3.3 inches. Length of the phalanges of the inner toe, — proximal phalanx, 3 inches; the second, 2 inches; the third, 3.4 inches (?): of the second toe, — the proximal, 2.4 inches; the second, 2.5 inches; the third, 2.9 inches; the fourth, 2.6 (?) inches: of the proximal metacarpal bone of the third and fourth toes, 3.5 inches; of the second do., 4 inches: of the first phalanx of the third toe, 2 inches; of the second, 2 inches; of the distal, 3.8 (?) inches: of the outer toe, — the proximal, 1.6 inch; the second, 1.6 inch; the distal, 5.4 inches (?). Divarication of the axes of the feet and the line of direction, 15°. Distance of the middle of the heel from the line of direction, 2.5 inches. Integuments of the bottom of the feet rugose and irregularly papillose. Track shown, of the natural size, with the papillose impressions, on Plate 12, fig. 1.

Locality. — South Hadley, near the house of Pliny Moody, Esq., by whom it was discovered and preserved, and the specimen, the only one known, deposited in the cabinet of Amherst College, where it is numbered 234. Mr. Moody was the first person in the Connecticut valley who recognized the fossil footmarks found there as those of birds; having spoken, more than forty years since, of those on No. 61 of my cabinet as made by "poultry," or by "Noah's raven." Hence it has seemed to me but justice that his name should be attached to this most remarkable species.

Affinities of the Genus. — Its biped character is evident from

the sketch (Plate 12, Fig. 2), which is copied from the only slab yet found with the tracks of this animal. The number of toes directed forward, and especially the number of phalangeal impressions, forbid us to class it among birds. There is, however, some resemblance between its foot and that of a frog in an embryotic state; and such analogies are important, because the adult developments of the early geological periods correspond best to the embryo structure of living animals. Hence there is at least a probability, that this animal was a biped batrachian; and what a monster, with feet 20 inches long and 12 wide! No such biped batrachians, indeed, now live; but some exist with only two feet. For an animal so large, its tracks are more nearly in a right line than we should expect, and its steps shorter; an indication of short legs.

In the *American Journal of Science*, Vol. IV. of the New Series, I have given full details respecting this track and its affinities. But I do not judge it expedient to repeat them all here. And yet so remarkable an animal — the most extraordinary of all those discovered by their tracks — could not properly be passed in silence in an attempt to give a monograph of this subject. Although a sketch of the slab containing the tracks of this species is given in that work, yet I have thought its exhibition here would be appropriate; and it is accordingly given on Plate 12, fig. 2, reduced eighteen diameters. It contains four tracks of the *Otozoum*, of which *A* is the most perfect. The two rows of tracks, *a*, *a*, &c., *b*, *b*, &c., belong to the *Brontozoum parallelum;* besides which a large part of the surface is covered with rain-drops in relief, as are all the tracks.

Genus XIII. PALAMOPUS.

Bipedal; tetradactylous; toes all directed forward, spreading moderately; leptodactylous; essentially plantigrade.

Species 1. Palamopus Dananus. (Pl. XI. Figs. 1, 2.)

No. 149 in Cabinet.

Angle between the inner and second toes, 25°; between the second and third, 30°; between the third and fourth, 15°; between the inner and outer, 67°. Length of the inner toe, 2 inches; of the second, 2.5 inches; of the third, 4.7 inches; of the outer, 2.3 inches; of the third or longest toe beyond the others, 2.7 inches. Distance between the tips of the first and second toes, 2.4 inches; between the second and third, 3.4 inches; between the third and fourth, 3 inches; between the outer ones, 4.7 inches. Length of the heel, 3.7 inches; breadth behind, 2 inches; wider before. Probably web-footed. Length of the foot, 8.5 inches; of the step, 21 inches. Axis of the foot and line of direction coincident.

Remarks. — The above dimensions were measured from Plate 11, fig. 1. Fig. 2, which is the next track on the only slab of this species yet discovered, appears to have been somewhat distorted by a subsequent track of *Brontozoum giganteum* on the same stone. It is possible, however, that this was not the cause of the difference between them.

This track was discovered by Mr. William S. Clarke, of the Senior Class in Amherst College, on the railroad, in the south-east part of Northampton. It is dedicated to S. L. Dana, M. D., LL. D., of Lowell.

Affinities of the Genus. — The resemblance between the tracks of this genus and the feet of some living batrachians is rather

striking. Some of the Ranidæ have only four toes on their fore feet. Now, as we have evidence of the probable existence, during the triassic period, of the biped batrachian *Otozoum*, we may, with no little probability, refer the *Palamopus* to the same tribe, until proof shall be obtained of its quadrupedal character. The *P. Dananus* is the only fossil animal in New England whose tracks decidedly indicate webbed feet.

Group VI. QUADRUPEDAL BATRACHIANS.

Quadrupeds, with 4 to 5 blunt pachydactylous toes, and webbed feet, especially the fore feet. Heels broad and irregular. Impression of the toes on the mud uniform through their entire length (i. e. not showing phalangeal enlargements). Rudiment of a sixth toe on the hind foot, and of a fifth toe on the fore feet (?).

Genus XIV. THENAROPUS, *King*.

Figured and described by Dr. King, in American Journal of Science, Vol. XLVIII. p. 348.

Description the same as that of the Group.

Species 1. Thenaropus heterodactylus, *King*.
(Pl. XVI. Figs. 1, 2.)

No. 191 in Cabinet.

Fore foot. — Toes four, with the rudiment of a fifth (?) on the inside, shown on the track by a protuberance. Divarication of the lateral toes, 90° ; of the inner and second toes, 20° ; of the second and third, 30° ; of the third and fourth, 40°. Length of the inner toe beyond the web, 1.2 inch ; of the second toe, 1.4 inch ; of the third, 1.5 inch ; of the fourth, 1.1 inch ; of the foot,

4.2 inches. Rudiment (?) of the fifth toe shown by a protuberance on the inside of the heel. Breadth of the heel, or hind part, 2.7 inches; of the toes, from 0.6 to 0.9 inch. Distance from tip to tip of the lateral toes, 4.5 inches; of the first and second, 1.5 inch; of the second and third, 1.8 inch; of the third and fourth, 2 inches. Toes blunt. Angle between the axis of the foot (a line drawn from the extremity of the heel to the middle point between the second and third toes) and the line of direction, 35°.

Hind foot. — Five toes, with the rudiment of a sixth (?) on the inside. Divarication of the outer toes, 75°; of the inner and second, 15°; of the second and third, 20°; of the third and fourth, 10°; of the fourth and fifth, 28°. Length of the inner toe beyond the web, 1.6 inch; of the second, 1.8 inch; of the third, 2.4 inches; of the fourth, 3.1 inches; of the fifth, 0.9 inch; of the foot, 5.5 inches; of the step, 9 to 16 inches. Distance between the hind and fore feet on the same side, 0 to 1 inch. Angle of the axis of the hind foot with the line of direction, 0° to 30°; usually coincident. Distance between the two rows of tracks, 6 to 8 inches; between the tips of the lateral toes, 4 inches; between the first and second, 1.2 inch; between the second and third, 1.5 inch; between the third and fourth, 1.2 inch; between the fourth and fifth, 3.2 inches. Width of the heel, about 2.2 inches. Tracks of the fore and hind foot shown, of the natural size, in a normal position, on Plate 16, figs. 1, 2.

Remarks. — The tracks of this animal were first described by Dr. Alfred T. King, in the *Proceedings of the Academy of Natural Sciences, Philadelphia*, for November and December, 1844, and in the *American Journal of Science*, Vol. XLVIII., p. 348. They occur in Westmoreland county, Pennsylvania, in the rocks of the coal formation, about 800 feet below its top. The sketch, Plate 16,

figs. 1, 2, of the natural size, representing a hind and fore foot, is copied from a very distinct specimen, sent me by Dr. King. The above description has been derived chiefly from the same slab, No. 191 of my Cabinet. On that slab are several mud veins, some of which proceed directly from the tips of the toes. This is, in fact, just what we might expect from the desiccation of the mud; though, to an unpractised eye, it might throw doubt over the whole subject.

Affinities of the Genus. — The anatomist cannot examine the tracks of this animal, or the sketches which I have given, without at once perceiving their resemblance to those of some living batrachians. Their semi-palmate character, the number and bluntness of the toes, and deficiency of claws, the want of phalangeal impressions, the relative length of the toes, the supposed rudiments of an additional toe, bear a striking analogy to the feet of the *Hyla Seurii* and *H. Gaimardi*, for instance, figured in the *Dict. Class. d'Hist. Nat.*, Plate 125. Even the relative length of the toes is the same, the outer toe but one being the longest. The *Thenaropus*, however, did not move by leaps; but as a tortoise; and it is possible that it might have been a chelonian. More probably, however, it was a batrachian; and being, with the exception of an unknown reptile discovered in the carboniferous rocks of Nova Scotia by Mr. Logan, the only example of vertebral animals so low in the series of rocks, it possesses a peculiar interest.

Genus XV. ANOMŒPUS.

Hind feet plantigrade, three-toed (four-toed ?); all the toes pointing forward. Heel long, extending to the tarsal joint. Fore foot quinquefid, digitigrade. All the toes pachydactylous, and making phalangeal impressions.

Remarks. — The second species of this genus was described by me in 1840, in my Massachusetts Report, with figures, (Plate 48, figs. 44, 45,) under the name of *Sauroidichnites Barrattii.* The evidence then discovered did not prove it to be a quadruped, although I strongly suspected this must be the case. The other species, the *A. scambus*, was first described by Dr. Deane, as a quadruped, in the *American Journal of Science*, Vol. XLIX. p. 80, and re-described in the same work, New Series, Vol. III. p. 78. Dr. Deane, however, has represented the hind leg as wanting altogether in a foot, and the lower leg as doubled down upon the long tarsus, or heel; and he supposes that from the animal's "peculiar organization, one set of feet did not touch the earth" (*American Journal of Science*, Vol. XLIX. p. 80). Having carefully examined the original specimen from which his drawings and description were taken, belonging to T. Leonard, Esq., of Greenfield, as well as others in Mr. Marsh's cabinet and in my own, I cannot doubt that the hind foot is most distinctly represented in nearly every case, as I have shown it on Plate 13, figs. 1 and 3, and on Plate 21, fig. 1, and on Plate 21, fig. 3, though as to the fourth toe I am not certain; and the heel of the hind foot has sometimes a peculiarity of structure, which might readily suggest the idea of the lower leg folded upon the tarsus; but I am not prepared thus to explain the slight longitudinal ridges we sometimes find upon it. But, however that may be, I cannot doubt that the hind foot had three stout, very distinct toes, very much resembling some of the tridactyle feet already described; for I find them on nearly every specimen I have seen; and although we might say of one instance, that the heel happened to come in contact with a track of *Brontozoum* directly before it, we cannot thus explain the numerous cases exhibited upon the plates above referred to; the originals of which

may be seen in the possession of Mr. Leonard, Mr. Marsh, or myself, by naturalists who would make sure of the correctness of my delineations. I will add, however, that the examination of the characters of this genus has cost me more labor and perplexity than that of any other described in this paper; and it would not be strange, if different observers should not entirely agree as to some of the features of its tracks.

Species 1. ANOMŒPUS SCAMBUS. (Pl. XIII. Figs. 1–6.)

Am. Jour. of Science, Vol. XLIX. p. 80, and Vol. III. p. 78, New Series.

Hind foot.—Pachydactylous; three-toed (four-toed ?). Divarication of the lateral toes, 45° to 50°; of the inner and middle toes, 20° to 25°; of the middle and outer toes, 20°. Toes usually nearly straight, but sometimes curved. Heel 4.2 inches long, expanding towards the posterior part. Lower leg above the tarsal joint sometimes making an impression on mud (see Pl. 13, fig. 4). Phalangeal impressions on mud three (?) by the inner toe, 0.7, 0.7, 0.8 inch, respectively; three by the middle toe, 1.1, 1, 0.7 inch; and five by the outer toe, 0.8, 0.8, 0.6, 0.6, 0.6 inch. Lateral distance between the extremity of the heels in the two tracks, 4 to 5.8 inches. Angle between the axis of the foot and the line of direction, 0° to 20°. Distance between the tips of the lateral toes, 2.7 inches; between the inner and second toes, 1.9 inch; between the second and third, 1.8 inch. Projection of the middle toe beyond the rest, 1.2 inch. Length of the middle toe, 3.2 inches; of the inner toe, 2.4 inches; of the outer toe, 3.3 inches; of the foot, 6 to 8 inches; of the step, usually about 9 inches.

Fore feet. — Quinquefid, pachydactylous; digitigrade. Divarication of the outer toes, excluding the hind toe, 75° to 90°; of

the inner and second toes, 20° to 35° ; of the second and third, 10° to 25° ; of the third and fourth, 30° to 45°; of the middle and hind toes, 90° to 100°. Length of the inner toe, 1 inch; of the second, 1.3 inch; of the third, 1.5 inch; of the fourth, 1.2 inch; of the hind toe, 1 inch. Number of phalangeal impressions made by the inner toe, two, 0.4, 0.3 inch, respectively; by the second, three (?), 0.3, 0.3, 0.3 inch; by the third, four, 0.4, 0.3, 0.3, 0.3 inch; by the fourth, three, 0.4, 0.4, 0.3 inch; by the hind toe, two, 0.4, 0.4 inch. Angle between the axis of the foot and the line of direction, 25° to 50°. Distance of the middle of the heel from the line of direction, 2 inches. Track of the hind foot, of natural size, shown on Plate 13, fig. 1; of the fore foot, on fig. 2. The hind foot, also, is shown on fig. 3, with perhaps a fourth toe. Figs. 4, 5, and 6 are also tracks of this or an allied species; the toes on the hind foot being more or less indistinct, and the leg above the tarsal joint making an impression on fig. 4.

Locality. — Turner's Falls, Gill.

Remarks. — The great difficulty of ascertaining the characters of this species, and the paucity of specimens, have made it necessary to give numerous sketches, some of which have been already referred to. Plate 21, fig. 1, is a true copy, reduced to one sixth of the natural size, of a slab four feet by two, belonging to T. Leonard, Esq., which that gentleman has very liberally allowed me to study and to copy. Upon it may be seen one row of seven or eight tracks of a *Brontozoum*, probably *B. gracillimum;* two parallel trails of a tortoise, the *Helcura littoralis*, to be described on a subsequent page; several insulated tracks, perhaps of *Brontozoum*, and also of the present species of *Anomœpus*, both hind and fore feet. The impressions *a* and *b*, of hind feet, and *c* and *d*, of fore feet, are the most interesting, because they appear to have been made

by the animal when at rest upon all its feet, and certainly look like the imprints of a frog, scarcely less than a foot in diameter; or, possibly, a tortoise.

In order to show how great changes of tracks frequently occur on layers of rock only an inch apart, I have given, on Plate 21, fig. 2, the under side of the above slab, belonging to Mr. Leonard. Scarcely one of these tracks corresponds to those upon the upper side of the slab. Only one example of a track of *Anomœpus* occurs, though some of the other trifid feet may be the toes of the hind foot of that animal. We see, also, three tracks of what is probably the *Ornithopus gallinaceus*.

Plate 20, fig. 3, is copied from a slab in Mr. Marsh's collection, reduced to one third of its natural size. It seems to show a succession of the tracks of *Anomœpus scambus*, the last four very similar to those upon Plate 21, fig. 1; that is, they seem to have been made by the animal when sitting upon its haunches. Yet the left-hand hind track is greatly injured by another track of an animal moving in an opposite direction; and the three fragments of toes near it look like the fore feet of the *Anomœpus*. If so, the heel of the hind feet did not reach the surface.

Plate 20, fig. 9, is a sketch, reduced three times, from a small slab presented me by Dr. Deane. It exhibits several tracks, more or less perfect, very similar to those of the slabs above described. In two cases, at least, on this slab, we seem to have little else but the impression of the heel, with a part of the lower leg (*a* and *b*). Yet a little in advance of *a*, we have impressions (*c*), indistinct I admit, of a sort that reminded me of the feet of certain batrachians; for example, the *Anolis Edwardsii*, of whose feet I have given a sketch on Plate 20, fig. 7, copied from Griffith's Cuvier, Vol. IX. p. 228. Yet I am by no means confident that I rightly

understand this case. But the statement may lead others, who have better opportunity, to reach the truth. The imprints of the fore feet on this slab, Plate 20, fig. 9, do not well correspond with those of the *Anomœpus scambus*, as given on the other drawings; and I am not without suspicion that it shows us tracks, not only specifically, but even generically, different from the *Anomœpus scambus*. I might add, that the term *scambus* (crooked leg) was derived from this slab, and may prove inappropriate to the species.

Plate 13, fig. 3, is copied from No. 170 of my cabinet. I cannot resist the impression that it has a fourth toe, as represented, though the specimen is not one of the most distinct. It shows, also, a rather remarkable ridge, common in this species, represented by a dotted line; the specimen appearing somewhat as if two heels lay side by side. I am not prepared to explain it; nor can I admit that it results from an impression of the leg above the tarsal joint.

Species 2. Anomœpus Barrattii. (Pl. XIV. Fig. 1.)

Sauroidichnites Barrattii, Mass. Geol. Report, Plate 30, fig. 1.

Nos. 1, 139, in Cabinet.

Hind foot. — Five-toed; plantigrade: toes pachydactylous, clawed, curved. Heel long. Divarication of the outer toes, 95° to 130°; of the inner and second, 20° to 45°; of the second and third, 40° to 50°; of the third and fourth, 30° to 40°; of the fourth and fifth, 10° to 20°. Length of the inner toe, 1.2 to 1.8 inch; of the second, 1.5 to 2 inches; of the third, 2 to 2.4 inches; of the fourth, 2 to 2.1 inches; of the fifth, 1.4 to 1.7 inch; of the heel to the tarsal joint, 4.5 (?) inches; of the foot, 7.5 inches. Versed sine of curvature in the middle toe, 0.4 inch; in the fourth,

0.15 inch. Length of the step, 11 to 14 inches. Leg above the tarsal joint often making an impression in walking, several inches in length, which forms an angle with that of the long tarsus, of about 35°, indicating a sprawling mode of progression, as is shown on Plate 14, fig. 1.

Fore feet. — Very similar to those of the first species; but my specimens of these are too imperfect for description.

Localities. — Plate 20, fig. 6, was taken from a specimen presented me by Dr. Barratt, of Middletown, to whom the species is dedicated, because discovered by him. (See *Mass. Geol. Report*, Vol. II. p. 477.) The specimen from which the sketch, Plate 14, fig. 1, is taken, was found at Marsh's Quarry, in Montague, but was much injured before I found it. I feel confident, however, that the dotted lines represent it as it was originally, although that part of the specimen is wanting. The five toes on the hind foot of this species clearly distinguish it from the *Anomœpus scambus.* When I described the tracks of this species in the *Massachusetts Geological Report,* I had no certain evidence of its quadrupedal character, though strongly suspecting it to have been made by a quadruped.

Genus XVI. ANISOPUS.

Quadrupedal; hind feet nearly twice as long as the fore ones, and considerably wider. Both hind and fore feet four-toed. In walking, the hind foot was brought up nearly into the place of the fore one. Tracks but a little to the right and left of the line of direction. Foot pachydactylous.

Species 1. Anisopus Deweyanus. (Pl. XVI. Figs. 5, 6.)

Sauroidichnites Deweyi, Trans. Assoc. Amer. Geologists, Plate 11, fig. 9.

Nos. 1, 37, 136, in Cabinet.

Hind foot. — Pachydactylous. Divarication of the lateral toes, 45° ; of the inner and second, 20° ; of the second and third, 10° ; of the third and fourth, 10°. Length of the inner toe, 0.5 inch ; of the second, 0.7 inch ; of the third, 0.8 inch ; of the fourth, 0.5 inch. Breadth of the foot from tip to tip of the outer toes, 1.4 inch ; from first to second, 0.6 inch ; from second to third, 0.45 inch ; from third to fourth, 0.4 inch ; at the roots of the toes, 1.2 inch. Length of the heel, 0.9 inch ; of the foot, 1.7 inch ; of the step, 7 to 7.5 inches ; the same for the fore feet. Track of the fore foot usually a little inside of the hind one. Angle between the axis of the foot and the line of direction, to the right and left, 15° to 40°. Distance of the middle of the heel from the line of direction, 0 to 1.5 inch. Width of the toes, 0.2 to 0.3 inch.

Fore foot. — Divarication of the toes the same as in the hind foot. Length of the inner toe, 0.2 inch ; of the second, 0.5 inch ; of the third, 0.6 inch ; of the fourth, 0.35 inch. Breadth from tip to tip of the lateral toes, 0.7 inch ; from the first to the second, 0.25 inch ; from the second to the third, 0.25 inch ; from the third to the fourth, 0.3 inch. Length of the foot, 0.6 inch. Position of the foot, in regard to the line of direction, the same as the hind feet. Width of the toes, 0.1 to 0.2 inch. Track shown, of the natural size, fore and hind feet, on Plate 16, figs. 5, 6, from different specimens.

This species is dedicated to my early friend, Rev. Chester Dewey, LL. D., of Rochester.

Remarks. — This was the first animal whose tracks were recognized as those of a quadruped, in the valley of Connecticut River. I first described them in my Report on the Geology of Massachusetts, from a specimen from Middletown, on which the inner toe

had been worn off, and I then supposed that a three-toed animal must be a biped. I suggested, however, their resemblance in other respects to those of a marsupial quadruped, but left the case unexplained. This was in 1840. At the meeting of the Geological Association in Boston, in 1842, I described the same track, from a specimen discovered by Dr. Deane, and presented to me, under the name of *Sauroidichnites Deweyi*. This description, with a drawing, was published in the Transactions of the Association, and I there stated that "this is the first example in which any of the numerous tracks upon the sandstone of the Connecticut valley were made by a quadruped." Dr. Deane, in 1845, published a drawing and description of the same specimen, as containing the tracks of a quadruped. But the discovery of still better specimens, from one of which (No. 136 of my cabinet) Plate 22, fig. 1, was copied exactly, gives us a clearer insight into the character of the animal, especially as to its mode of progression. We can see on that drawing, that the feet on the right side of the animal uniformly pointed a little to the right, and those on the left to the left; and that it must have advanced by regular steps, like a common mammiferous quadruped. The slab on which this row of tracks occurs is represented on Plate 20, fig. 10. On it are four rows of *Æthyopus minor*, and two tracks of *Helcura littoralis*. Plate 23, fig. 3, shows another slab in Mr. Marsh's cabinet, with tracks of *Anisopus*.

Species 2. Anisopus gracilis. (Pl. XVI. Figs. 3, 4.)

Nos. 141, 158, in Cabinet. Numerous specimens in Mr. Marsh's cabinet.

Hind foot. — Divarication of the lateral toes, 40°; of the inner and second, 15°; of the second and third, 10°; of the third and

fourth, 15°. Length of the inner toe, 0.4 inch; of the second, 0.6 inch; of the third, 0.9 inch; of the fourth, 0.7 inch. Distance from tip to tip of the outer toes, 0.75 inch; of the inner and second, 0.3 inch; of the second and third, 0.3 inch; of the third and fourth, 0.25 inch. Breadth of the posterior part, 0.5 inch; of the toes, about 0.1 inch. Length of the foot, 0.9 inch; of the step, 5.7 inches. Angle between the line of direction and the axis of the foot, 20°. Feet on the right side of the animal diverging to the right; those on the left side to the left.

Fore foot. — Divarication of the toes the same as in the hind feet. Axis of the fore foot essentially parallel to that of the hind foot. Track of the fore foot a little nearer to the line of direction than that of the hind foot, and just in advance of the latter. Length of the inner toe, 0.2 (?) inch; of the second, 0.4 inch; of the third, 0.55 inch; of the fourth, 0.4 inch. Distance from tip to tip of the outer toes, 0.4 inch; of the inner and second, 0.2 inch; of the second and third, 0.15 inch; of the third and fourth, 0.25 inch. Width of the toes (average), 0.08 inch. Length of the foot, 0.55. Track shown, of the natural size, both hind and fore feet, and in a normal position with respect to each other, on Plate 16, figs. 3, 4.

Remarks. — One of the most distinct of my specimens indicates a very short fifth toe on the outside of the foot, as is shown on Plate 16, fig. 4. But I am not confident whether such is the case, and therefore omit it in the description. This species is distinguished from the previous one, by being more slender and delicate in all its parts. It occurs at Turner's Falls.

Plate 22, fig. 2, is a sketch of two tracks of the hind and fore feet, copied from No. 158 of the Cabinet, and reduced to one third of its natural size. For so small an animal, the length of the step is very great.

Genus XVII. HOPLICHNUS.

Feet hoof-shaped; producing a track like a horseshoe. Quadrupedal; hind and fore feet of nearly equal size.

Species 1. Hoplichnus quadrupedans. (Pl. XVI. Figs. 7, 8.)

Nos. 181 – 183, in Cabinet.

Anterior part of the foot semicircular, or forming a portion of a circle. Impression very much resembling a horseshoe. Diameter, 1.5 to 2.2 inches. Middle of the foot extending, when the animal was walking, from one to five inches to the right and left of the line of direction. Track shown, of the natural size, on Plate 16, figs. 7, 8.

Locality.—Turner's Falls, at the Ferry, on the Gill side of the river; on coarse micaceous sandstone.

Remarks. — The sketches on Plate 16, figs. 7 and 8, give the shape of the depression in this track; but no toes are visible. It is possible that the surface on which they occur was a little below where the animal trod, and that the layer of rock above would have shown the toes. It is possible, also, that a slight movement of the sand, after the imprint was made, might have obliterated the toes; yet no reason can be given why in that case the impression should have been left so uniformly of a circular form. The specimens, however, do show a slight ridge in some cases, extending backward from the track, as if a gentle current had slightly moved the sand. But there can be no doubt that this animal is generically different from any other described in this paper; for the fore and hind feet are nearly of equal size, and more nearly circular than any other species. The sketch, on Plate 22, fig. 3, taken from No. 181 of my cabinet, will satisfy any one acquainted with ichnology, that

these tracks were made by a quadruped; because we find two tracks near each other, succeeded by a long interval, and these in two rows. The sketch is reduced four times, but is an exact copy of the original. Those acquainted with the history of fossil footmarks will recognize the tracks of this species as identical with those described by Dr. Cotta, in 1839, in Saxony; sketches of which are given in the *American Journal of Science*, Vol. XXXVIII. p. 255. The only difference is, that ours are more perfectly rounded. Dr. Cotta regards the extremity of the arch as the ends of two toes, making the animal bidigitate. But our specimens make it more probable that those extremities were the posterior part of the foot, and that the toes were in front, and very short. He likewise could not find any succession of tracks; but our specimens, although not showing all we could wish, make it extremely probable that the tracks had a quadrupedal origin; and hence the specific name.

Affinities of the Group. — I have already said enough, I trust, as to the relations of the first genus (*Thenaropus*) to batrachians, and even to the Ranidæ. The relations of the second genus (*Anomœpus*) may be a little more doubtful. The sprawling character of its hind feet, so as to bring even the lower leg upon the ground, corresponds better to some chelonians than to batrachians. Yet the position of the feet, as shown on Plate 21, figs. 1 and 3, when the animal was at rest, corresponds so nearly to that of the Ranidæ, that I think we may safely refer it to that tribe. Such a position of the animal looks as if it moved by leaps, like the common frog. But it is a large animal to advance in this manner; I mean, large among batrachians; nor do the drawings, Plate 20, fig. 9, and Plate 21, fig. 3, confirm this impression. If so large an animal had advanced by leaps, is it possible that we should not meet with

some cases in which the foot slid forward as it came to the ground, with such a *vis a tergo* as its weight would give? Yet the impressions of its feet are as distinct and undisturbed, as if they had been each one put down with the nicest care. I hesitate, therefore, to assert that leaping was the animal's mode of progression.

The form of the feet, and the number and position of the toes, as well as the broad posterior part of the foot, seem to ally the genus *Anisopus* to batrachians. But what living batrachian places its feet in walking as did these fossil species? It is, indeed, quite remarkable. Although the feet were of very unequal size, yet it would seem from Plate 22, fig. 1, that it walked very much like such quadrupeds as the cat, the dog, and the fox; that is, the tracks vary but little from a right line; nor is the axis of the foot turned much aside from the line of direction. Indeed, its mode of walking was much more like that of a mammiferous quadruped, with long, perpendicular legs, than like that of sprawling reptiles. I have almost persuaded myself that these animals are marsupial quadrupeds. For we know that this tribe did exist in the oolitic period, and would it be strange, if they should be shown to have appeared one geological period earlier, that is, in the triassic period? The presumption, however, from the general analogies of fossil nature is, that they were batrachians; but if they were so, their structure must have been quite peculiar. For the present, however, I leave them among the batrachians. By comparing their tracks with those of the Proteus, given on Plate 19, fig. 3, the form of the toes will be seen to be quite similar; but how different the mode of progression!

As to the *Hoplichnus*, its mode of walking must have been similar to that of quadrupeds; but since we know as yet so little

of its characters, I leave it with the batrachian tribe, on the ground of general analogies only.

Group VII. LACERTILIANS?

Quadrupedal; fore feet much the smaller. Toes varying from three to five. Heel very long.

Genus XVIII. MACROPTERNA.

Hind feet four-toed; fore feet three to four-toed. Heel long, especially upon the hind feet. Fore feet usually digitigrade, and much smaller than the hind ones. Hind feet usually plantigrade.

Species 1. Macropterna rhynchosauroidea. (Pl. XV. Fig. 9.)

Ornithoidichnites Rogersi, Trans. Am. Geol. Assoc., Plate 11, fig. 7.

Ornithoidichnites minimus, in part, Mass. Geol. Report, Plate 45, fig. 41, and Plate 42, fig. 30.

Nos. 77, 105, 107 – 110, 120, 148, 184, 233, in Cabinet.

Hind feet. — Tetradactylous, leptodactylous. Divarication of the toes, excluding the short one behind, 80°; of the inner and middle toes, 30°; of the middle and outer toes, 50°. Length of the middle toe, 0.7 inch; of the inner toe, 0.45 inch; of the outer toe, 0.5 inch; of the fourth or hind toe, 0.25 (?) inch; of the foot, 1.8 inch; of the step, 3.8 to 5.5 inches; of the heel, 1.2 inch. Width of do., which is uniform throughout, 0.15 inch. Angle made by the axis of the foot with the line of direction, 10° to 50°. Distance of the end of the heel from that line, 0 to 1 inch. Position of the axis of the foot in successive steps, nearly parallel. Distance from tip to tip of the lateral front toes, 0.75 inch; from

the inner to the second toe, 0.5 inch; from the second to the third, 0.55 inch; from the third to the fourth, 0.4 inch (?).

Fore feet. — Tridactylous. Divarication of the toes essentially as in the hind feet. Length of the middle toe, 0.4 inch; of the inner toe, 0.3 inch; of the outer toe, 0.25 inch; of the heel, 0.25 inch; of the foot, 0.6 inch. Position of the axis of the foot and distance from the line of direction, same as in the hind feet. Distance from tip to tip of the lateral toes, 0.5 inch; of the inner and middle toes, 0.3 inch; of the middle and outer toes, 0.3 inch. A track of the hind foot is always preceded by one of the fore foot, distant usually a little more than an inch. A track of a hind and a fore foot, in their normal position, is shown on Plate 15, fig. 9.

Remarks. — The track of this remarkable animal was long mistaken by me for that of *Argozoum minimum*, and was supposed to be that of a biped, probably a bird. But the discovery of the long heel, and the almost constant occurrence of a large and small track together, showed that it was of quadrupedal origin. It is possible, indeed, that what I call a heel may be a hind toe running directly backwards, as is seen in some birds, and as the track of such lizards as the *Phyllurus Cuvieri* and *Milii* would exhibit. (See *Dictionnaire Classique d'Histoire Nat.*, Plate 120.) But its great length on the hind feet makes it more probably, in these tracks, an imprint of the tarsal bone. The specimens from which Plate 22, figs. 4, 5, were sketched were obtained from Wethersfield. That from which fig. 6 was taken was from the north part of South Hadley; and is given in my Geological Report on Massachusetts, Plate 42, fig. 30, as a track of *Argozoum minimum*. Since on this specimen no marks of the heel are visible, the resemblance of the tracks to those of that biped is very striking; and has led me into some doubt whether the *Argozoum minimum* be not

in fact a digitigrade impression of the *Macropterna.* But since the toes of the former are much more divaricate and curved than those of the latter, I do not give in to this opinion, and have retained the former as a species. The specific name of the *Macropterna* is founded upon the fact that the *rhynchosaurus,* according to Mr. Ward, had but three toes in front, although a saurian lizard. Although the fore foot frequently shows a heel, I have found one on the hind foot in only two instances. Yet they are very distinct examples; though I cannot understand why it should not be shown in other cases, where the foot made as deep an impression. But I have seen too many similar omissions in other tracks, whose characters are well known, to be surprised at it.

The fourth toe on the hind foot I have found in only one instance; and in that case only the extremity of the toe reached the ground; this may explain why it left an impression so seldom. The specimen is so distinct, that I can hardly doubt the existence of such a toe on the animal.

The figures of this species, on Plate 22, are all copied from specimens, and are reduced to one third of the natural size.

Locality. — Wethersfield, on red shale; also at the Horse Race, in Gill, on fine gray micaceous sandstone; and at South Hadley, on gray micaceous sandstone.

Species 2. MACROPTERNA RECTA. (Pl. XV. Fig. 6.)

Sauroidichnites palmatus, Mass. Geol. Report, Plate 34, fig. 15.

Nos. 31 – 33, in Cabinet.

Hind foot. — Tetradactylous, leptodactylous, plantigrade. Divarication of the outer toes, 75° to 80°; of the inner and second, 10°; of the second and third, 30° to 35°; of the third and fourth, 35°. Length of the inner toe, 0.9 inch; of the second, 1.25 inch;

of the third, 1.6 inch; of the outer, 1.1 inch; of the heel, 1.4 inch. Width of the heel, 0.3 to 0.5 inch. Length of the foot, 3 inches; of the step, 7.7 inches. Distance between the tips of the lateral toes, 1.6 to 1.8 inch; between the inner and second, 0.7 inch; between the second and third, 0.9 inch; between the third and fourth, 1.2 inch. Axis of the foot nearly coincident with the line of direction. Toes nearly straight.

Fore foot. — Tetradactylous, leptodactylous, imperfectly plantigrade. Divarication of the lateral toes, 100°; of the inner and second, 30°; of the second and third, 35°; of the third and fourth, 35°. Length of the inner toe, 0.25 inch; of the second, 0.4 inch; of the third, 0.9 inch; of the fourth, 0.7 inch; of the heel, 0.5 inch. Width of the heel, 0.8 inch (*length*, literally). Distance between the tips of the lateral toes, 1.2 inch; between the first and second, 0.3 inch; between the second and third, 0.7 inch; between the third and fourth, 0.6 inch. Axis of the foot nearly coincident with the line of direction. Toes somewhat curved inward. Distance between the tracks (that is, between the tip of the middle toe behind and the heel of the fore foot), 0 to 1 inch.

Locality. — Horse Race, Gill; on gray micaceous sandstone.

Remarks. — The specimen from which the above description was taken is the same as that from which I drew up my description of the *Sauroidichnites palmatus* of the *Massachusetts Geological Report.* I then regarded the animal as a biped, though suspecting it might turn out to be a quadruped. That conjecture has been verified in a rather singular manner. Very recently, as the specimen would not split well, I attempted to grind down its upper surface upon a grindstone. This brought to light a part of two smaller and similar tracks, a little in advance of the larger ones; which I conceive to settle the question as to their quadrupedal origin. It

also brought to view a long heel on the hind foot. Of the fore foot I had insulated and perfect specimens, from which the sketch, Plate 15, fig. 6, was taken. Plate 22, fig. 6, shows the position and character of all the tracks on the slab, the front ones being now in a great measure ground away. This discovery renders it necessary to remove this species from the genus *Palamopus*, which is supposed to be composed of bipeds. It approaches so near the *Macropterna* in its general character, that I place it there provisionally. Yet both feet have four toes; but it would not be strange if the other species of this genus should be found to have a short toe on the fore feet; so that I do not think this fact a sufficient reason for referring the *M. recta* to another genus. There is somewhat the appearance of a toe running obliquely backwards from the end of the heel of the hind foot, where are placed dotted lines on Plate 15, fig. 6. But I am not sure of it, and, besides, it seems to be on the outside of the heel, which is a presumption against its being a toe; as the hind toe usually proceeds from the inside of the heel.

Species 3. MACROPTERNA DIVARICANS. (Pl. XV. Fig. 7.)

Fine specimens in the cabinet of Mr. Dexter Marsh in Greenfield, and in that of Professor Shepard in Amherst College.

Hind feet. — Tetradactylous. Divarication of the outer toes, 90° to 100°; of the inner and second, 25°; of the second and third, 35°; of the third and fourth, 32°. Length of the inner toe, 0.45 inch; of the second, 0.6 inch; of the third, 0.7 inch; of the fourth, 0.6 inch; of the heel, 1.2 inch; of the foot, 1.9 inch; of the step, 3.3 inches. Heel somewhat wedge-shaped, varying in width from 0.2 to 0.6 inch. Distance from tip to tip of the lateral toes, 1.3 inch; from the inner to the second toe, 0.55 inch;

from the second to the third, 0.6 inch; from the third to the fourth, 0.5 inch. Angle between the axis of the foot and the line of direction, 0° to 80°. Toes all turned outward; much spreading. Feet turned outward. Distance of the heel from the line of direction, 0 to 1.1 inch.

Fore feet. — Pentedactylous. Divarication of the outermost of the four front toes, 125°; of the inner and second, 50°; of the second and third, 50°; of the third and fourth, 25°. Length of the inner toe, 0.25 inch; of the second, 0.45 inch; of the third, 0.4 inch; of the fourth, 0.3 inch; of the fifth, 0.1 inch; of the foot, 0.6 inch. Foot digitigrade. More distant from the line of direction in walking than the hind toe, but less divaricate. Track from 0 to half an inch in advance of the hind foot. Tracks of both feet, of the natural size, and in normal position, shown on Plate 15, fig. 7.

Locality. — Turner's Falls; below the Falls, on the Gill side.

Remarks. — The first specimen of this species, discovered by Mr. Marsh and now in his cabinet, exhibits only the hind toes. As soon as I saw it, I recognized it as nearly related to the *Sauroidichnites palmatus* of my Massachusetts Report, and probably identical with it; although I had then no certain evidence that any of them were quadrupeds, as we had then on the specimen only an alternation of the right and left hind foot, as shown on Plate 19, fig. 5, which is a copy of the slab above referred to in Mr. Marsh's cabinet, reduced to one third of its natural size. When, however, I discovered the small tracks connected with the large ones of *Macropterna recta* (*S. palmatus*), I hastened to Greenfield to reexamine Mr. Marsh's specimen, in the hope of finding there also the fore foot. To my surprise and gratification, I found that he had obtained from a new locality, below Turner's Falls, most beau-

tiful specimens of this species, with the small fore foot as distinct as the hind one. One of these specimens is sketched on Plate 22, fig. 8, reduced three times. It was, however, only on a fine specimen in Professor Shepard's cabinet that I have discovered a fifth toe on the fore foot, too distinct to be doubted. I am still somewhat suspicious that this and the preceding species (*M. recta*) may turn out to be the same; although the latter is a good deal larger, the toes much straighter (hence the specific name), and, if I have not mistaken the character of the fore foot, this also differs a good deal, having a large heel. Both these species differ from the *M. rhynchosauroidea*, by having a quite different heel, and four or five toes, instead of three, on the fore foot.

Plate 22, fig. 10, is a sketch, of the natural size, of two rows of tracks on a slab in Mr. Marsh's collection. The fore tracks are much better developed than the hind ones. They appear to be the smallest of all tracks yet discovered. If they are the *M. divaricans*, they must have been made by the young of that species.

Genus XIX. XIPHOPEZA.

Tetradactylous: three toes directed forward; the fourth being a prolongation backward of the outer toe. Heel stout, expanding posteriorly. Hind and fore feet unequal, resembling three swords, or daggers, in a complex sheath.

Species 1. Xiphopeza triplex. (Pl. XV. Fig. 8.)

Specimens in the cabinet of Mr. Dexter Marsh.

Hind feet. — Three toes directed forward. Divarication of the outer toes, 80° to 90°; of the inner and middle, 40°; of the middle and outer, 50°; of the middle and hind, 130°; of the hind and outer, 180°. Length of the inner forward toe, 0.8 inch; of

the middle, 1.5 inch; of the outer, 1.1 inch; of the hind, 0.5 inch; of the heel, 1.2 inch; of the foot, 2.6 inches; of the step, 2.5 to 3.5 inches; of the middle front toe beyond the rest, 0.6 inch. Greatest width of the heel, near its posterior part, 0.45 inch; near the roots of the toes, 0.2 inch; between the tips of the lateral forward toes, 1.5 inch; between the inner and middle, 1 inch; between the middle and outer, 1.1 inch. Axis of the foot nearly parallel to the line of direction. Distance of the axis of the foot from that line, 1.4 inch.

Fore feet. — Much smaller than the hind feet; but only a few of the toes can be seen upon the specimens yet found of the tracks, — certainly not more than three. Enough, however, is seen to show the quadrupedal character of the animal. On Plate 22, fig. 9, copied from a slab in Mr. Marsh's cabinet, and reduced three times, we see the hind feet arranged in two nearly parallel rows, with traces of a few of the fore feet in such a position as we should expect in the tracks of a quadruped. The hind foot, of the natural size, with a part of the fore foot, is shown on Plate 15, fig. 8.

Locality. — Turner's Falls, on the Gill shore, below the Falls; on very soft gray micaceous sandstone.

Remarks. — Excluding the heel, the hind foot of this animal corresponds almost exactly to the *Ornithopus gallinaceus*, though smaller. But the heel and its quadrupedal character make it very distinct. Yet if the *Ornithopus Adamsanus* shall be found to be a quadruped, it will form a gigantic species of this genus; and perhaps it ought to be placed here now, since we have no evidence that it is not a quadruped, and its large heel certainly makes it probable that it is. The tracks of this species, and also those of the *Macropterna divaricans* and *Harpedactylus gracilis*, were very recently discovered by Mr. D. Marsh, a little below Turner's Falls,

in Gill, where the highly inclined shales are laid bare. Mr. Marsh has generously allowed me to take sketches from his specimens, and to give the species scientific names; although he expects to give a popular description of them, in the *American Journal of Science*, before the publication of this paper.

Among Mr. Marsh's specimens, found at the above-named locality, is one of which a sketch of two rows of tracks, reduced three times, is given on Plate 23, figs. 1 and 2. I cannot satisfactorily refer this track to any known species, though perhaps it may belong to the one last described; that is, an impression considerably below the layer on which the animal trod. It is chiefly remarkable for the axis of the foot being turned so much inward, towards the line of direction, and for the wire-like fineness of the extremities of the toes. But the different tracks are so unlike and so imperfect, that I conclude they are a good deal altered from the original, and prefer not to describe them as a new species.

Affinities of the Group. — One cannot look at the succession of tracks and the form of the feet in this group, as exhibited upon the accompanying drawings, and much less upon the originals, without being struck with their resemblance to the feet and the tracks of small Lacertilia. The number of toes, indeed, corresponds perhaps more nearly to certain batrachians, say the *Salamandridæ* and *Sirenidæ*, which very commonly have only four toes, at least on the fore feet. But the long heel corresponds better to the lizards; and, upon the whole, I incline to consider them as such. And yet it is extremely difficult to decide between these two classes. There is one fact, especially, in respect to the first two species of *Macropterna*, that does not well correspond to either tribe. I mean the small deviation of the animal's feet to the right and the left of the line of direction. What living Lacertilia or

Batrachia would walk so nearly in a right line? Yet the tracks of *Xiphopeza* and the *Macropterna divaricans* show sprawling legs, like existing lizards. Most of the fossil animals, also, brought up the hind foot in walking more nearly into the place vacated by the fore foot than existing lizards or batrachians do. It would seem as if these animals must have had longer and more upright legs than any of these tribes now alive. This is, however, less the case in the present group than in some of Group VI. I ought to add, that there is one living species of salamander, and perhaps more, with feet exceedingly like those of the *Macropterna rhynchosauroidea;* namely, with four toes on the hind feet, and three on the fore feet. This is the *Salamandre de Trois Doigts* of Sonnini and Latreille, from whose work on reptiles the outline of this animal, given on Plate 20, fig. 8, was copied. Yet how much more sprawling and divaricate must be the tracks of this animal than those of the *Macropterna!*

Group VIII. CHELONIANS.

Quadrupedal; fore feet less than the hind ones. Animal with sprawling or trailing legs.

Genus XX. ANCYROPUS.

Hind feet the larger; three leptodactylous toes in front, and one proceeding from the posterior part of the heel. Toes on the fore foot, three in front; perhaps one behind. Heels before and behind, long and crooked. Toes of both feet much curved outward. Tracks in two parallel rows. Feet slightly resembling an anchor, and hence the name.

Species 1. ANCYROPUS HETEROCLITUS. (Pl. XV. Figs. 3 – 5.)

Sauroidichnites heteroclitus and *Jacksoni*, Mass. Geol. Report, Plate 30, figs. 2 and 3.

Nos. 2 – 6, 130, 156, in Cabinet.

Hind foot. — Heel 1.5 inch long, 0.7 inch wide. Length of the inner toe, 0.4 inch; of the second, 0.6 inch; of the third, 0.5 inch; of the hind toe, 0.5 inch; of the foot, 3 inches; of the step, from 4.5 to 5.5 inches. Versed sine of the outward curvature of the toes, from 0.4 to 0.7 inch, making them very crooked. Distance from tip to tip of the lateral toes, 0.9 inch; of the inner and second, 0.45 inch; of the second and third, 0.45 inch; of the middle front and the hind toes, 1.8 inch. Heel at its posterior extremity adhering to the mud so as to raise a singular conical eminence (shown in the drawings), as it was lifted up. Tracks in two rows, from 6 to 7 inches apart; the toes turned outward, and the axis of the foot parallel to the line of direction.

Fore foot. — Heel 1.8 inch long, and 0.3 inch broad; crooked; the hind part turned towards the line of direction, opposite to that of the toes. Length of the inner toe, 0.3 inch; of the middle, 0.4 inch; of the outer, 0.35 inch. Perhaps a fourth toe on the inner side of the heel. Distance from tip to tip of the lateral toes, 0.5 inch; of the inner and second, 0.3 inch; of the second and third, 0.25 inch. Curvature of the toes the same as on the hind foot. Tracks of both the hind and fore feet shown, of the natural size, on Plate 15, figs. 3 – 5; the last two being of the hind foot.

Remarks. — Until recently I had found only insulated tracks of this genus, and I described the hind and fore feet as distinct species (*Geological Report*, p. 478, Plate 30, figs. 2 and 3). The discovery of the specimen of tracks from which Plate 19, fig. 4, was sketched, however, although quite imperfect, reveals the true char-

acter of the animal, and also the reason why some of the tracks were much narrower than others, namely, that one is the fore foot and the other the hind foot. It is quite possible, I think, that there may be four toes in front, certainly on the hind foot, which I take to be the largest, according to a general rule. Plate 15, fig. 5, copied from a track found at Wethersfield, so much resembles the others, that I do not separate them, although the former shows four distinct toes in front.

On Plate 19, fig. 4, one of the tracks seems to have a fourth toe proceeding from the outside of the heel. This is not quite certain, though I have endeavoured to copy the specimen. The inner hind toe, also, is wanting on that specimen. But it is not perfect enough to found any important conclusions upon it, save that it shows the manner in which the animal walked.

Genus XXI. HELCURA.

Quadrupedal; tail and feet trailing upon the ground.

Species 1. Helcura littoralis. (Pl. XV. Fig. 1.)

No. 136 in Cabinet. Specimens also in Mr. Marsh's cabinet.

Feet from 1.5 to 2.5 inches long, and from half an inch to an inch wide; tracks somewhat acuminate, as if the foot trailed on lifting it up, and the trail continuing often interruptedly to the next track. A similar trail, also, seems to have been made by the tail. Tracks somewhat in two rows; two tracks being usually near each other, and then a wider interval. Plate 15, fig. 1, is copied from No. 136, and represents a portion of the trail and tracks of this animal, of the natural size.

Remarks. — One cannot look upon the specimen (No. 136 of my cabinet) from which Plate 15, fig. 1, was copied, without being

struck with the resemblance to the trail of a tortoise upon mud. Yet after the animal passed, a thin layer of mud was deposited, after which other animals walked over it and a shower of rain fell upon it, so that the tracks of the *Helcura* are indistinct. The toes cannot be distinguished ; nor can the successive tracks of the same foot be seen very certainly. I cannot, however, doubt that these trails were made by a chelonian, and by a different species from any other whose tracks I have met upon this sandstone. They have been found only at Turner's Falls. A second fine example may be seen in Mr. Marsh's collection, a sketch of which is given on Plate 23, fig. 3. Plate 21, fig. 1, shows also the trail of *Helcura.*

Affinities of the Group. — It seems unnecessary to add much to the preceding descriptions, to make it probable that the genera *Ancyropus* and *Helcura* were chelonians. No other animals that I know of would leave such footmarks and trails. The approximation of the tracks, as shown on Plate 19, fig. 4, shows that the Ancyropians moved forward very slowly, just as tortoises now do. Their tail and feet, also, were frequently trailed over the mud, as was done by the Helcurans. And if I have not mistaken the characters of these genera, the conclusion seems forced upon us that they were chelonians.

Group IX. ANNELIDS or MOLLUSCS.

Track a curved or looped furrow, of various sizes.

Genus XXII. HERPYSTEZOUM.

Characters the same as those of the group.

Species 1. HERPYSTEZOUM MARSHII. (Pl. XVII. Fig. 1.)

Groove made by the progression of the animal, 0.2 inch wide. Shown, of the natural size, on Plate 17, fig. 1. Plate 23, fig. 4, shows another specimen, from Mr. Marsh's collection, greatly reduced.

Remarks. — This species was discovered at Turner's Falls, by Mr. Dexter Marsh, who, by indefatigable industry and tact, has obtained a very rich and valuable collection of the footmarks and other fossils of the Connecticut valley. Hence I have attached his name to this animal. This paper will testify, also, that he has discovered several other species described in it.

Species 2. HERPYSTEZOUM MINUTUM. (Pl. XVII. Fig. 2.)

Width of the groove made by the progression of the animal, 0.05 inch. Shown, of the natural size, on Plate 17, fig. 2.

Remarks. — The only difference between the two species of this genus consists in size, — that is, so far as we can judge from their track-way. Yet this difference is so great, that they must have been produced by different species. Both of them occur at Turner's Falls, on reddish shale.

Affinities of the Group. — The resemblance between the track-ways of these animals and those of certain annelids, especially the common earthworm, upon mud, is very striking. That such was the origin of the figure 1, Pl. 17, I have little doubt. Fig. 2 is rather larger than the earthworm produces, and it might have been made by a small mollusc. I more incline, however, to refer it to the Annelata.

GROUP X.

Feet didactylous; toes unequal, in shape somewhat like the drag used in tilling land.

Genus XXIII. HARPAGOPUS.

Characters the same as those of the group.

Remarks. — I have hesitated long before referring the marks described under this group to the tracks of animals, because they differ so much from the feet of any animals with which I am acquainted. But there is so much uniformity among these impressions, that we must refer them to some common cause; some cause, too, that made an impression on the surface of mud, rather than to a body interposed between layers of mud; and I know of no agency, but the feet of animals, that could have made such impressions. Moreover, we do know of some living animals (as the crustaceans), that have didactylous feet. Heteroclitic, then, as these markings are, I must refer them to the tracks of animals, till proved to be something else.

Species 1. HARPAGOPUS GIGANTEUS. (Pl. XVIII. Fig. 1.)

Nos. 137, 152, in Cabinet.

Divarication of one pair of toes, 15°; of the other, 25°. Length of the longest toe in one pair, 10.5 inches; of the shortest do., 7 inches; of the longest in the other pair, 1.3 inches; of the shortest do., 5 inches (as far as it reached the ground). Thickness of the toes, 1.4 to 1.7 inch. Feet pointing in nearly opposite directions. One foot shown, of the natural size, on Plate 18, fig. 1. On Plate 23, fig. 5, is a reduced copy of the slab, showing both feet, and also a row of the tracks of *Brontozoum parallelum* and *Æthyopus minor*.

Remarks. — It may seem an insuperable objection to considering the sketches of Pl. 23, fig. 5, as the feet of the same animal, that they point in opposite directions. But a reference to the feet of some reptiles will show that such would be the tracks which they would make. Plate 23, fig. 6, is an outline of the *Algyra barbarica*, copied from Griffith's Cuvier, Vol. IX. p. 212. Of a similar character is the outline on Plate 23, fig. 7, of the *Salamandra Beecheyi*, copied from the *Zoölogy of Beechey's Voyage*, Plate 31, fig. 3.

I would not intimate that the *Harpagopus giganteus* was a batrachian or lacertilian; for I have no evidence of another set of tracks corresponding to those sketched on Plate 23, fig. 4. Indeed, I know of no living animal whose feet correspond to these impressions. Yet some crustaceans have bifurcated extremities; as was the case with some encrinites. Then one cannot but think, in this connection, of the *ichthyopodulites* of Dr. Buckland, or petrified track-ways of certain ambulatory fishes, whose fins struck the muddy bottom.

Locality. — Turner's Falls, where it was obtained by Mr. Marsh; and he has specimens in his cabinet.

Species 2. Harpagopus Hudsonius. (Pl. XVIII. Fig. 2.)

No. 127 in Cabinet.

Rows of tracks two, parallel, about a foot apart; feet didactylous; toes diverging about 40°; unequal in length; blunt; length from 2 to 3.5 inches; the axis of the foot lying nearly at right angles to the direction in which the animal moved. One foot of two toes shown, of the natural size, on Plate 18, fig. 2. Plate 24, fig. 1, shows a greatly reduced outline of a slab in my cabinet, taken from a sidewalk in New York.

Remarks. — These tracks occur in the Hamilton group of the Erie division of the New York system of rocks; and have been particularly described by me in Vol. XLVII. of the *American Journal of Science*, p. 314. I introduce this species here, because the tracks resemble in form the first species of this genus, although, if the animals that made them were similar, they must have been widely separated in age. I am unable to trace out any satisfactory affinities between the present species and any existing animals, although some crustaceans have extremities with a bifurcation similar to these tracks. On Plate 24, fig. 1, it will be seen that the tracks, or pairs of toes, are arranged somewhat in parallel lines.

Species 3. HARPAGOPUS DUBIUS. (Pl. XVIII. Fig. 3.)

Toes from one and a quarter to two and a quarter inches long, and half an inch wide, with rounded extremities; arranged somewhat on a line, across which the axis of the toes lies at an angle of about 50°. Impressions made by the toes shallow, yet distinct. Three impressions shown, of the natural size, on Plate 18, fig. 3.

Remarks. — The tracks of this species have less evidence of being those of an animal than the last, from the silurian rocks of New York. Still there is enough of general resemblance to the *H. Hudsonius*, especially in the form of the impressions and their arrangement along a line, to make it probable that both had a similar origin. This specimen was found by Dr. Deane, at Turner's Falls, and presented to me. I hope that time will throw more light upon it, as well as upon the other species of the genus. It has seemed to me that they exhibit too many evidences of organic origin to be passed in silence.

Conclusion. — I have thus presented the results of more than thirteen years' examination of an obscure and difficult branch of paleontology. In endeavouring to give definiteness and system to its materials, by an application of the laws of zoölogy and comparative anatomy, I know that I have undertaken a difficult task. It is no easy matter to restore animals from mere fragments of their skeletons; yet to recall them into existence from the evidence of their tracks must be still more perplexing. Hence I hope I may claim much indulgence from naturalists, in what they may regard as a bold attempt. Whether they admit my conclusions or not, I trust that they will see that this curious subject is making rapid progress. I had thought, long ago, that I had got nearly to the end of the chapter upon it, so far as the Connecticut valley is concerned. But within a year or two, and with comparatively feeble efforts, some of the most interesting and important of all the facts relating to footmarks have come to light, modifying considerably our previous conclusions, and giving us new and more remarkable insight into the former zoölogical condition of New England. It is no idle boast to say, that I have devoted much time, and labor, and thought, to these mementos of the races that, in the dawn of animal existence in the Connecticut valley, tenanted the shores of its rivers and estuaries. Whatever doubts we may entertain as to the exact place on the zoölogical scale which these animals occupied, one feels sure that many of them were peculiar and gigantic; and I have experienced all the excitement of romance, as I have gone back into those immensely remote ages, and watched those shores along which these enormous and heteroclitic beings walked. Now I have seen, in scientific vision, an apterous bird, some twelve or fifteen feet high, — nay, large flocks of them, — walking over the muddy surface, followed by many others of analogous character,

but of smaller size. Next comes a biped animal, a bird, perhaps, with a foot and heel nearly two feet long. Then a host of lesser bipeds, formed on the same general type; and among them several quadrupeds with disproportioned feet, yet many of them stilted high, while others are crawling along the surface, with sprawling limbs. Next succeeds the huge *Polemarch*, leading along a tribe of lesser followers, with heels of great length, and armed with spurs. But the greatest wonder comes in the shape of a biped batrachian, with feet 20 inches long. We have heard of the Labyrinthidon of Europe, — a frog as large as an ox; but his feet were only 6 or 8 inches long, — a mere pygmy compared with the *Otozoum* of New England. Behind him there trips along, on unequal feet, a group of small lizards and *Salamandridæ*, with trifid or quadrifid feet. Beyond, half seen amid the darkness, there move along animals so strange that they can hardly be brought within the types of existing organization. Strange, indeed, is this menagerie of remote sandstone days; and the privilege of gazing upon it, and of bringing into view one lost form after another, has been an ample recompense for my efforts, though they should be rewarded by no other fruit. But I will indulge the hope, that naturalists will not refuse them a name and a place on the register of preadamic existence.

⁂ In order to bring the most important of these characters under the eye at a glance, I have collected them in the appended table. The numbers are the mean of those given in the detailed descriptions, where there is any variation in the characters. For an easy comparison of species, this table will be convenient. But as it will explain itself, further description is unnecessary.

Explanation of the Plates.

N. B.—The tracks only of the species enumerated are represented.

Plate I.	Fig.	1.	Brontozoum giganteum.
II.	"	1, 2.	B. loxonyx.
	"	3.	B. gracillimum.
III.	"	1.	B. expansum.
	"	2.	B. Sillimanium.
	"	3, 4.	B. parallelum.
IV.	"	1.	Æthyopus Lyellianus.
	"	2, 3.	Æ. minor.
V.	"	1.	Steropezoum ingens.
	"	2.	S. elegans.
	"	3.	S. elegantius.
	"	4.	Ornithopus rectus.
	"	5.	Harpedactylus rectus.
VI.	"	1.	Argozoum Redfieldianum.
	"	2.	A. dispari-digitatum.
	"	3, 4.	A. pari-digitatum.
	"	5.	A. minimum.
VII.	"	1.	Platypterna Deaniana.
	"	2, 3.	P. tenuis.
	"	4.	P. delicatula.
	"	5.	Ornithopus Adamsanus.
VIII.	"	1.	O. gallinaceus.
	"	2.	O. gracilior.
	"	3.	O. loripes.
	"	4.	Plectropus longipes.

Plate IX.	Fig.	1.	Polemarchus gigas.
	"	2, 3.	Plectropus minitans.
X.	"	1–3.	P. longipes, on different layers.
	"	4.	Triænopus Baileyanus.
	"	5.	T. Emmonsianus.
	"	6.	Typopus abnormis.
XI.	"	1.	Palamopus Dananus; left foot.
	"	2.	P. Dananus; right foot.
XII.	"	1.	Otozoum Moodii.
	"	2.	Slab, with four tracks of O. Moodii, several of Brontozoum, and rain-drops.
XIII.	"	1.	Anomœpus scambus; hind foot.
	"	2.	A. scambus; fore foot.
	"	3.	A. scambus; hind foot, with perhaps four toes.
	"	4.	A. scambus? hind foot.
	"	5, 6.	A. scambus? fore feet.
XIV.	"	1.	A. Barrattii; left hind-foot.
	"	2.	Harpedactylus gracilis.
	"	3.	H. concameratus.
	"	4.	H. concameratus? hind foot?
	"	5.	H. concameratus? fore foot?
XV.	"	1.	Helcura littoralis.
	"	2.	Typopus?
	"	3.	Ancyropus heteroclitus; fore foot.
	"	4, 5.	A. heteroclitus; hind foot.
	"	6.	Macropterna recta; hind and fore foot.
	"	7.	M. divaricans; hind and fore foot.
	"	8.	Xiphopeza triplex; hind and fore foot.
	"	9.	Macropterna rhynchosauroidea; hind and fore foot.

Plate XV.	Fig.	10–13.	Triænopus Baileyanus, on successive layers of rock.
	"	14–16.	T. Emmonsianus, on successive layers.
	"	17–19.	Plectropus longipes, on successive layers.
XVI.	"	1.	Fore foot of Thenaropus heterodactylus.
	"	2.	Hind foot of the same.
	"	3, 4.	Hind and fore feet of Anisopus gracilis.
	"	5, 6.	Hind and fore feet of A. Deweyanus.
	"	7, 8.	Hoplichnus quadrupedans.
XVII.	"	1.	Herpystezoum Marshii.
	"	2.	H. minutum.
	"	3, 4.	Tracks of Platypterna Deaniana, on successive layers; fig. 3 being the highest.
XVIII.	"	1.	Harpagopus giganteus.
	"	2.	H. Hudsonius.
	"	3.	H. dubius.
XIX.	"	1, 2.	Ideal tracks of a quadruped.
	"	3.	Tracks of the Banded Proteus.
	"	4.	Reduced sketch of tracks of Ancyropus heteroclitus.
	"	5.	Do. of Macropterna divaricans.
	"	6.	" Triænopus Baileyanus and Emmonsianus.
	"	7.	" Typopus abnormis.
XX.	"	1.	Tracks reduced of Harpedactylus gracilis.
	"	2.	Foot of Lopholaimus antarcticus.
	"	3, 4.	Foot of Cathartes fœtens.
	"	5.	Foot of a Gryphus.
	"	6.	Track reduced of Anomœpus Barrattii.
	"	7.	Feet of Anolis Edwardsii.

Plate XX. Fig.	8.	Sketch of a Salamander, with three toes in front.
"	9.	Slab reduced of Anomœpus scambus.
"	10.	" " several species of animals.
XXI. "	1.	" " tracks of Anomœpus scambus, &c., the upper side.
"	2.	The under side of the same.
"	3.	Slab of same species, the upper side.
XXII. "	1.	Reduced slab of the tracks of Anisopus Deweyanus, upper side.
"	2.	Do. of Anisopus gracilis, under side.
"	3.	" Hoplichnus quadrupedans.
"	4 – 6.	" Macropterna rhynchosauroidea.
"	7.	" M. recta.
"	8.	" M. divaricans.
"	9.	" Xiphopeza triplex.
"	10.	Slab, natural size, of Macropterna divaricans?
XXIII. "	1, 2.	Slabs of an unknown species, reduced.
"	3.	Reduced slab, showing various species from Mr. Marsh's cabinet (Æthyopus, Anisopus, and Helcura).
"	4.	Herpystezoum Marshii, reduced.
"	5.	Slab reduced of Harpagopus giganteus, Brontozoum parallelum, and Æthyopus minor.
"	6.	Sketch of Algyra barbarica.
"	7.	" Salamandra Beecheyi.
XXIV. "	1.	Reduced slab of Harpagopus Hudsonius.
"	2.	" " H. dubius.
"	3.	" " Æthyopus minor.

Plate XXIV. Fig.	4.	Reduced slab of		Ornithopus loripes.
"	5.	"	"	Brontozoum Sillimanium.
"	6.	"	"	Harpedactylus concameratus.
"	7.	"	"	H. rectus.

A TABULAR VIEW

OF THE CHARACTERS OF THE TRACK DISCOVERED ANIMALS OF THE UNITED STATES

		Number of toes	Of the outer fore toes	Of the inner and second toes	Of the second and third toes	Of the third and fourth toes	Of the fourth and fifth toes	Of the hind toe and inner fore toe	Of the inner toe	Of the second toe	Of the third toe	Of the phalangeal impressions of the inner toe	Of the phalangeal impressions of the second toe	Of the phalangeal impressions of the outer toe	Of the ... middle toe
B[illegible] 1 giganteum,		3	40	22	15				10	12.5	12.5	18-44	34-3-26	33-35-21-24	1.75
2 Sillimanium,		3	35	25	15				4.4	6	5.5	14-11	12-13 12	08-07-09-11	1
3 isonyx,		3	28	17	1[illegible]				4.4	6	5.5	16-16	16 17-14	1-13-12-15	1
4 expansum,		3	60	25	30				3.2	4.6	4.9	13-12	14-13-13	16-12-09 13	11
5 gracillimum,		3	50	25	25				1.7	2.2	2	05 04	05-04 04	045-04-045-06	04
6 parallelum,		3	17	55	12				1.8	2.5	2	08 04	08-08-08	035-04-04-035	04
[illegible] 1 Lyellianus,		3	35	15	20				4.2	6.4	5.2	16-18	18-18-17	12 12-1-15	1
2 minor,		3	60	25	35				2.5	3.2	2.8	12 08	1-08-07	08 07-06-05	07
[illegible]pezoum 1 [illegible]gens,		3	60	15	20				0.75	1.3	1.025				
2 elegans,		3	62	35	30				2.5	4.4	2.8				
3 elegantius,		3	7[illegible]	[illegible]	4[illegible]				1.1	[illegible]	[illegible]				
Arg[illegible]zoum 1 Redfieldianum,			[illegible]		4				[illegible]	1[illegible]					
2 dispari-digitatum,			[illegible]	1	[illegible]				[illegible]						
[illegible]				1	4					1[illegible]	[illegible]				
4 [illegible],			[illegible]	[illegible]	4					[illegible]	7				
Platypterna 1 Deaneana,			[illegible]	[illegible]	[illegible]				[illegible]		1[illegible]				
[illegible]					2[illegible]										
[illegible]			1	[illegible]	[illegible]					1[illegible]	[illegible]				
Orn[illegible] 1 [illegible],		4	100	40	60			140	1.2	6.5	5.2				
2 gallinaceus,		4	7[illegible]	[illegible]	1[illegible]			1[illegible]		[illegible]	1[illegible]				
3 gracilior,		4	80	40	43			150	1.1	1.5	1.1				
4 [illegible]tripes,		4	100	50	50			150	3.75	5	4				
P[illegible]archus 1 gigas,		4	[illegible]	30	25			80	8.5	11.2	8.1				
Ch[illegible]tropus 1 [illegible]constans,		4	90	45	50			100	2.2	3.1	2.1				
2 longipes,		4	72	32	40			95	1.7	2.8	2.1				
[illegible]opus 1 Baileyanus,		4	37	18	18			35	1.9	2.9	2.2				
2 Emmonsianus,		4	50	25	25			115	1.8	2.7	1.9				
[illegible] 1 gracilis,		4	70	28	35			55	1.9	2.2	1.8				
T[illegible] 1 [illegible]formis,		1	35	20	15				1.3	2.8	1.8				
Otozoum 1 Moodii,		4	35	15	5	12			8.6	10.28	8	1 2-14 24	Second toe 25 29 26	[illegible]	8.5
[illegible]		4	[illegible]		[illegible]				[illegible]	[illegible]	1[illegible]				
[illegible]ropus 1 [illegible]dactylus,	Hind ft.	5	75	15	20	10	25		1.6	1.8	2.4				1.1
	Fore ft.	4	90	20	40	40			1.2	1.4	1.5				1.1
An[illegible]pus 1 [illegible],	Hind ft.	4	47	25	20				2.4	3.2	1.1	07-07-08	11-1-7	08 08-06-06 06	1.5 1.2 1
	Fore ft.	5	87	27	17	40		95	1	1.3	1.5	04-01	03 04 03	04-03-03 03	
2 Barrattii,	Hind ft.	5	12[illegible]	30	45	35	15		1.5	1.7	2.2				4 1.6
	Fore ft.	5													
An[illegible] 1 Deweyanus,	Hind ft.	4	45	20	10	1[illegible]			0.5	0.7	0.8				0.[illegible]
	Fore ft.	4	45	2[illegible]	10	1[illegible]			0.2	0.5	0.6				0.[illegible]
2 gracilis,	Hind ft.	4	40	15	10	16			0.4	0.6	0.[illegible]				0.7
	Fore ft.	5[illegible]	40	15	10	16			0.2	0.4	0.5				0.4
H[illegible] 1 quadrupedans,															
Mac[illegible] 1 rhynchosauroides,	Hind ft.	4	80	30	50				0.45	0.7	0.5				0.2[illegible]
	Fore ft.	4	80	30	50				0.3	0.4	0.25				
2 recta,	Hind ft.	4	77	1[illegible]	72	35			0.9	1.25	1.6				1.1
	Fore ft.	4	110	30	35	35			0.25	4	0.9				0.7
3 divaricans,	Hind ft.	4	65	25	35	72			0.45	0.6	0.7				0.6
	Fore ft.	5	125	50	50	45			0.25	0.45	0.4				0.5 0.1
Xiphopeza 1 triplex,	Hind ft.	4	90	40	50			140	0.8	1.5	1.1				
	Fore ft.	4(?)													
An[illegible] 1 heteroclitus,	Hind ft.	4							0.4	0.6	0.7				
	Fore ft.	4							0.3	0.4	0.35				
Harpagopus 1 giganteus,		2	15 to 25						5 to 7	10 to 13					
2 Hudsonius,		2	40						2	3.5					
3 dubius,															

The angular measures in the above table are given in degrees, the linear measures, in English inches and decimals of the same.

PLATE I.

Lith. of G & W. Endicott New York.


Fig 3
Fig 1
Fig 2

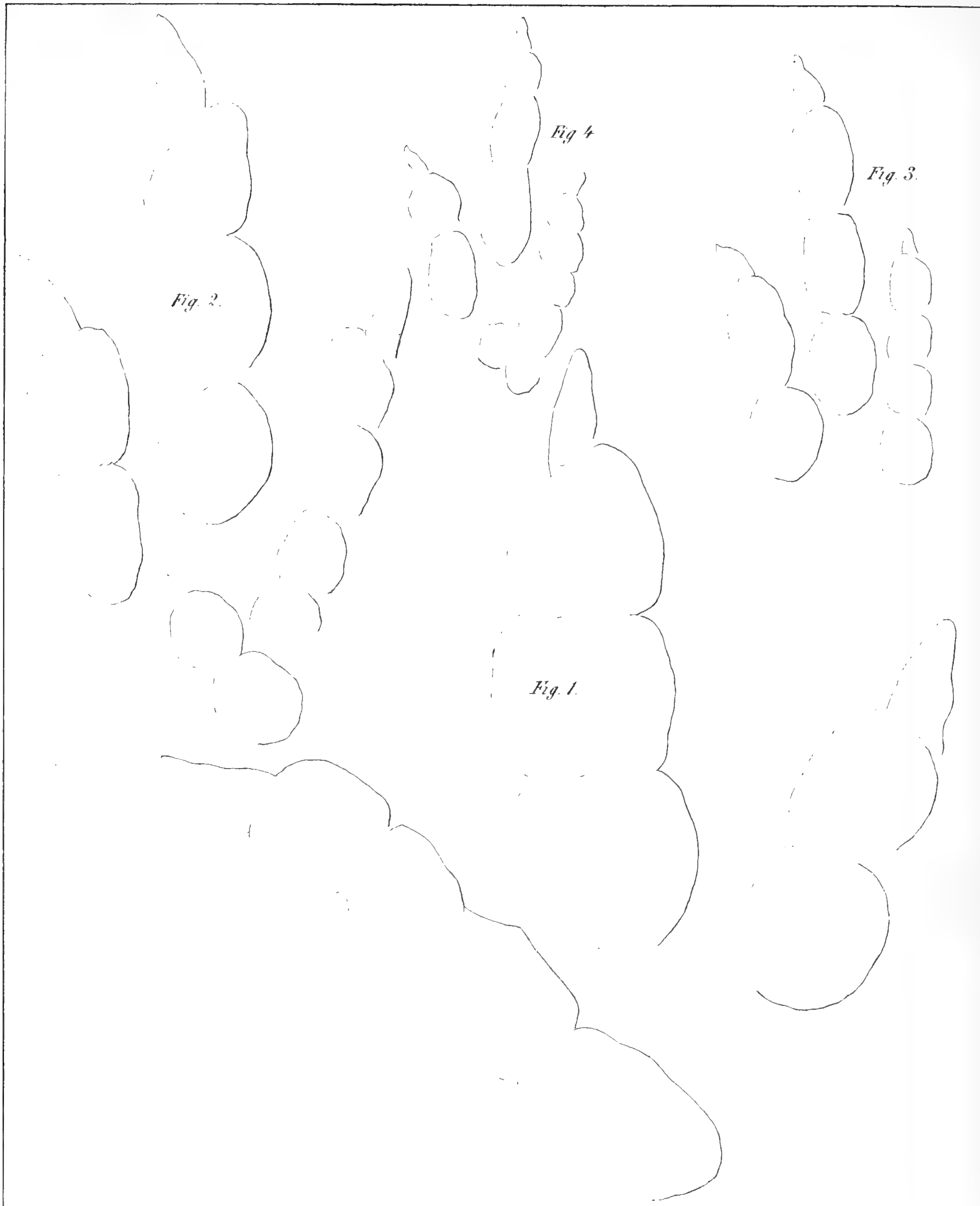
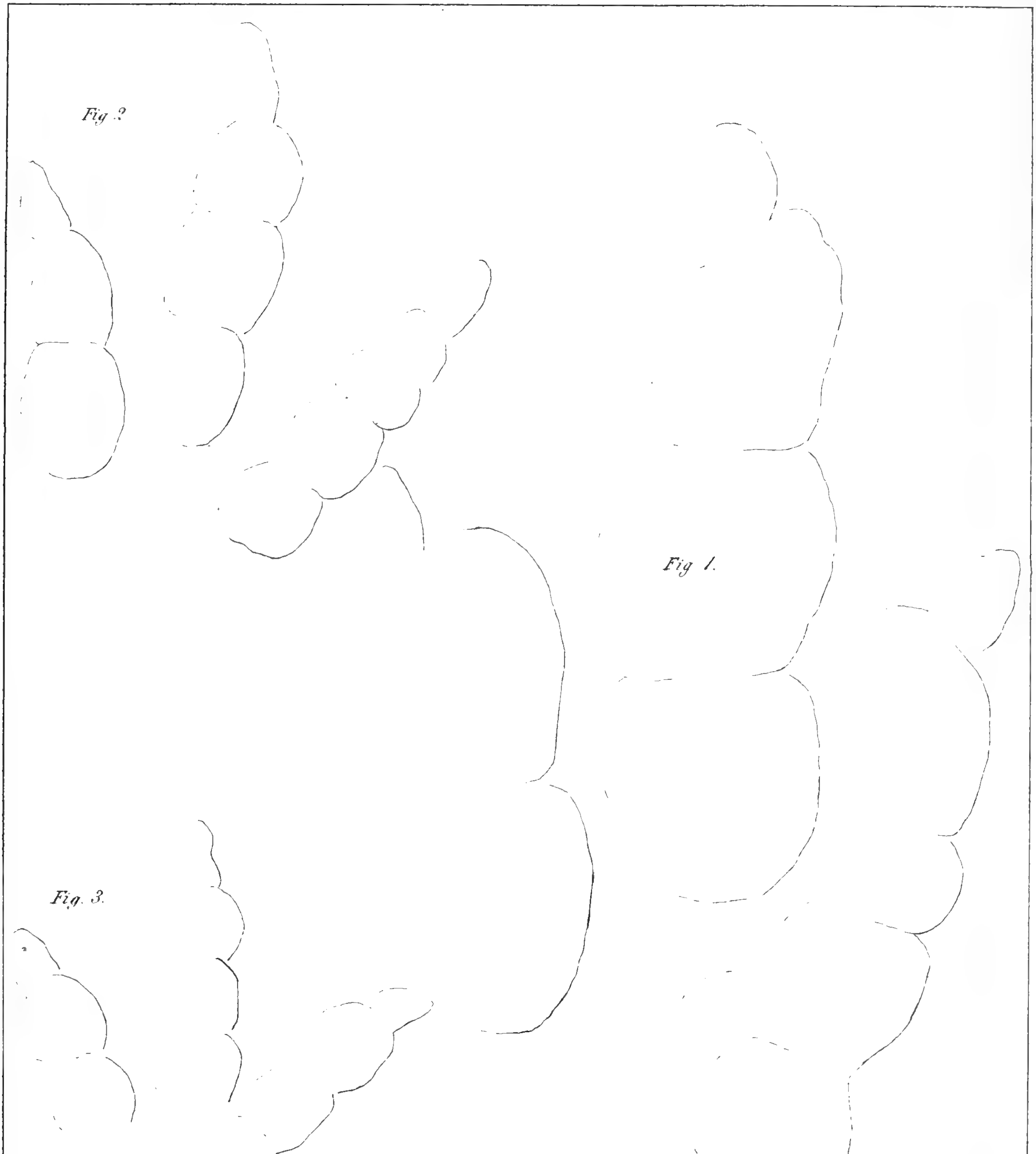
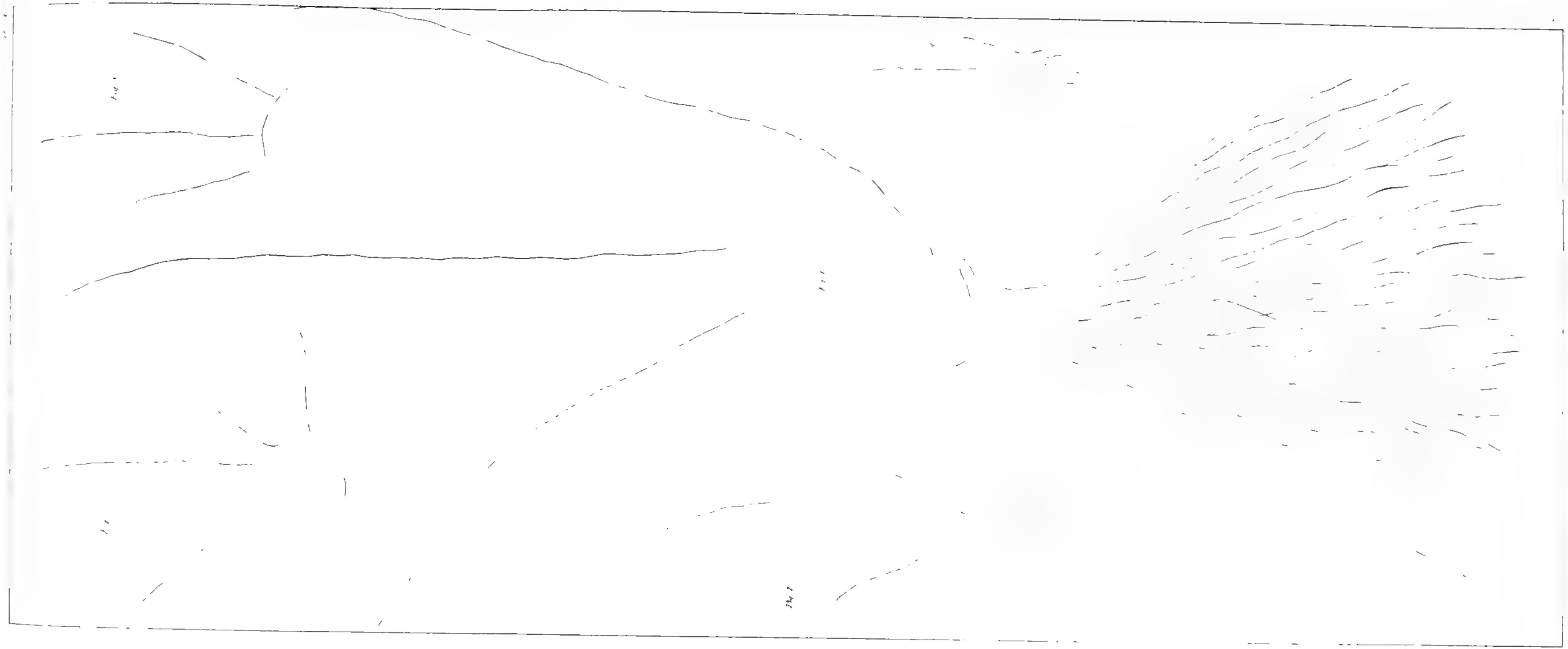


Fig 4
Fig. 3.
Fig. 2.
Fig. 1.



Lith. of G. & W. Endicott N. York



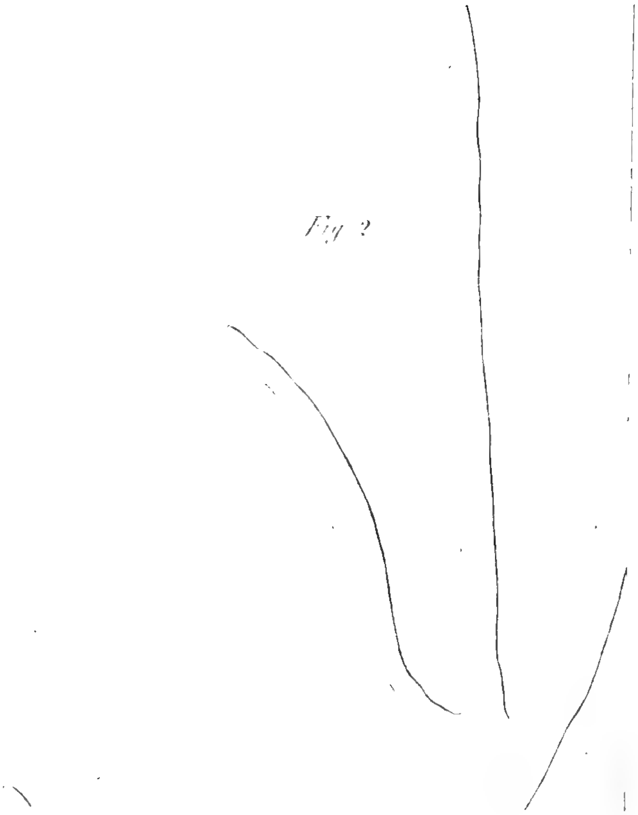
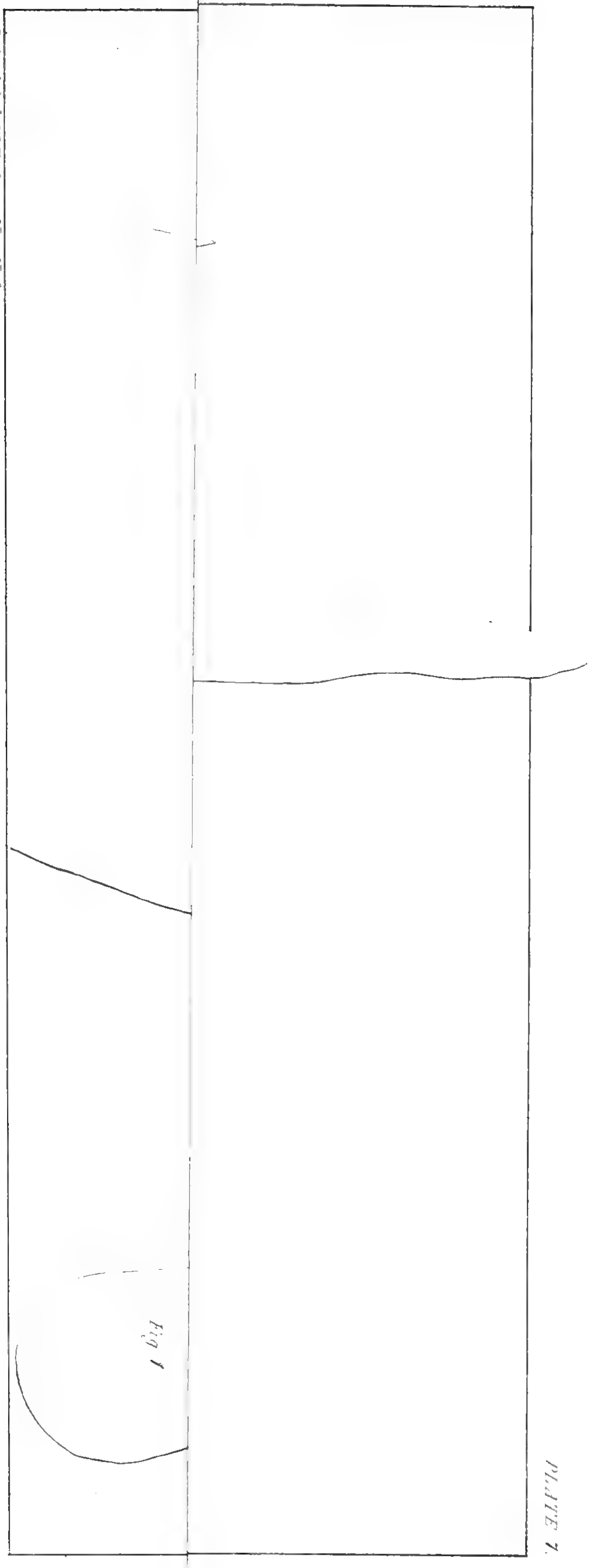


Fig 2



Lith of G. & W. Endicott New York

Fig 1

PLATE 7.

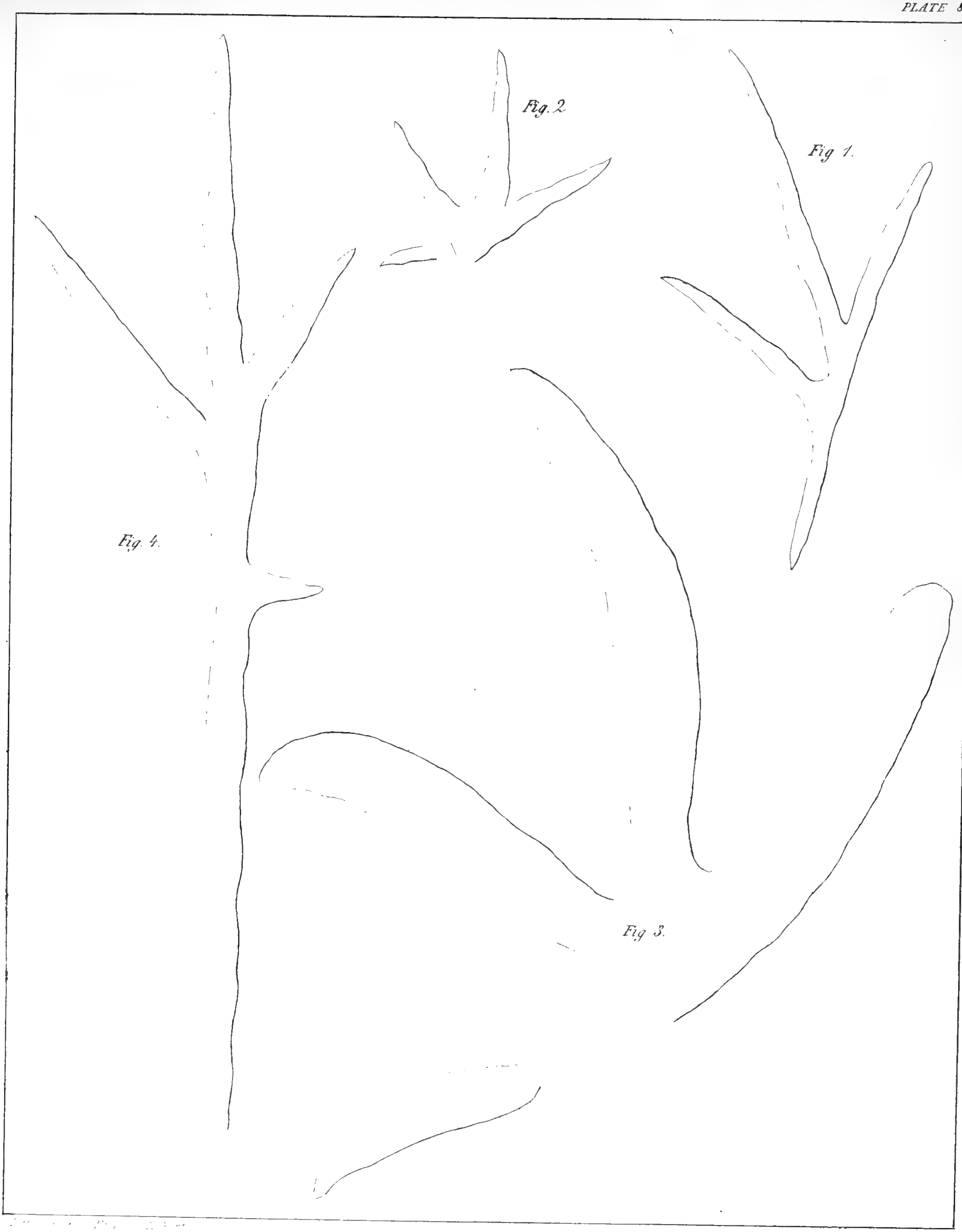
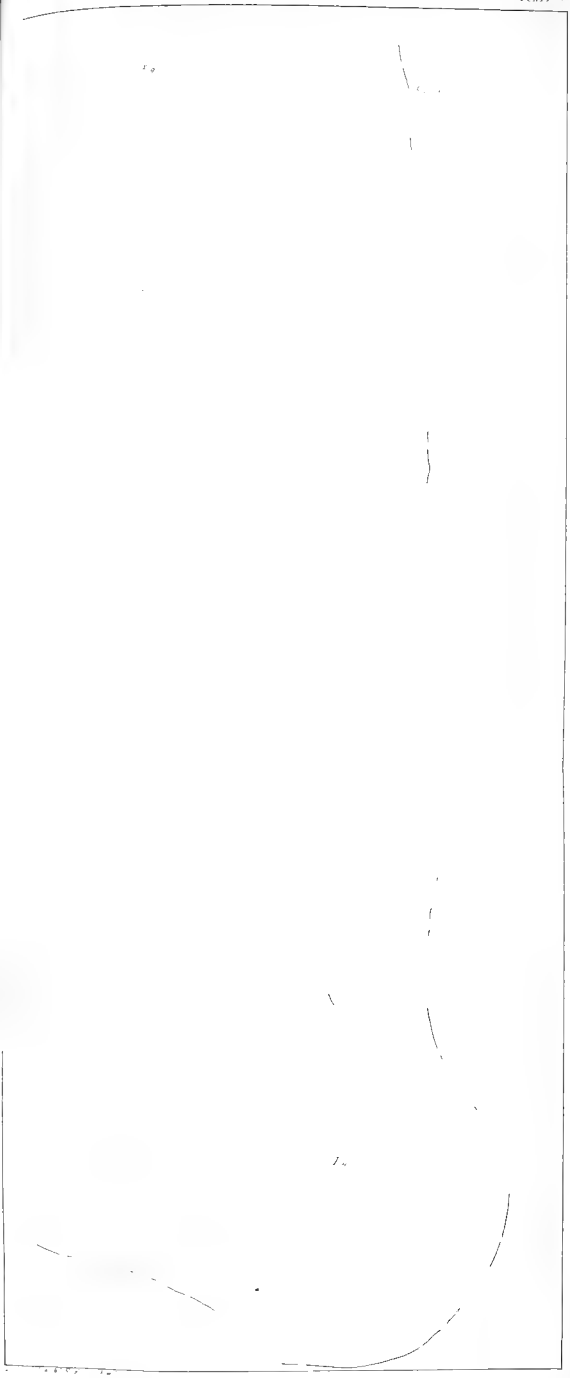
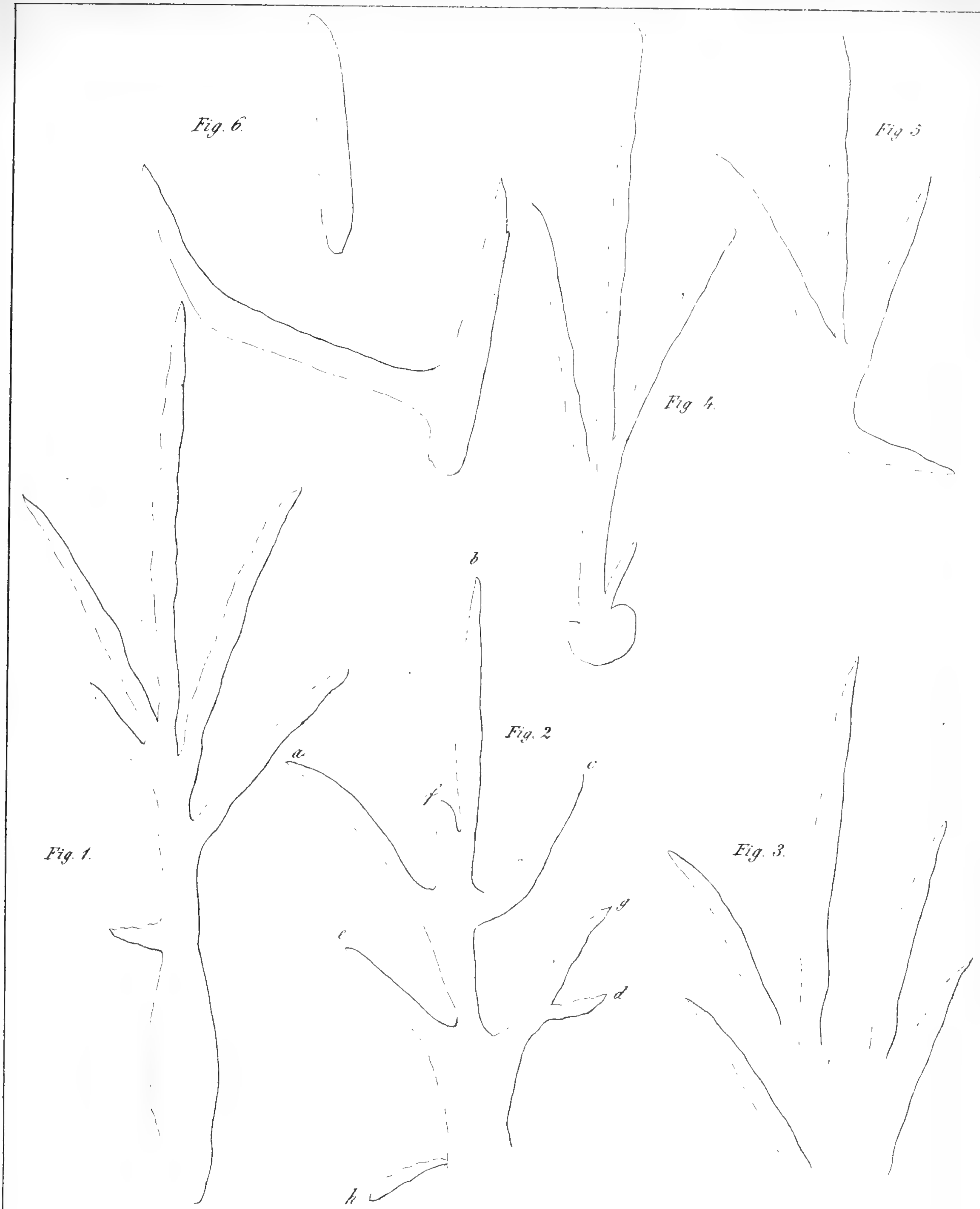
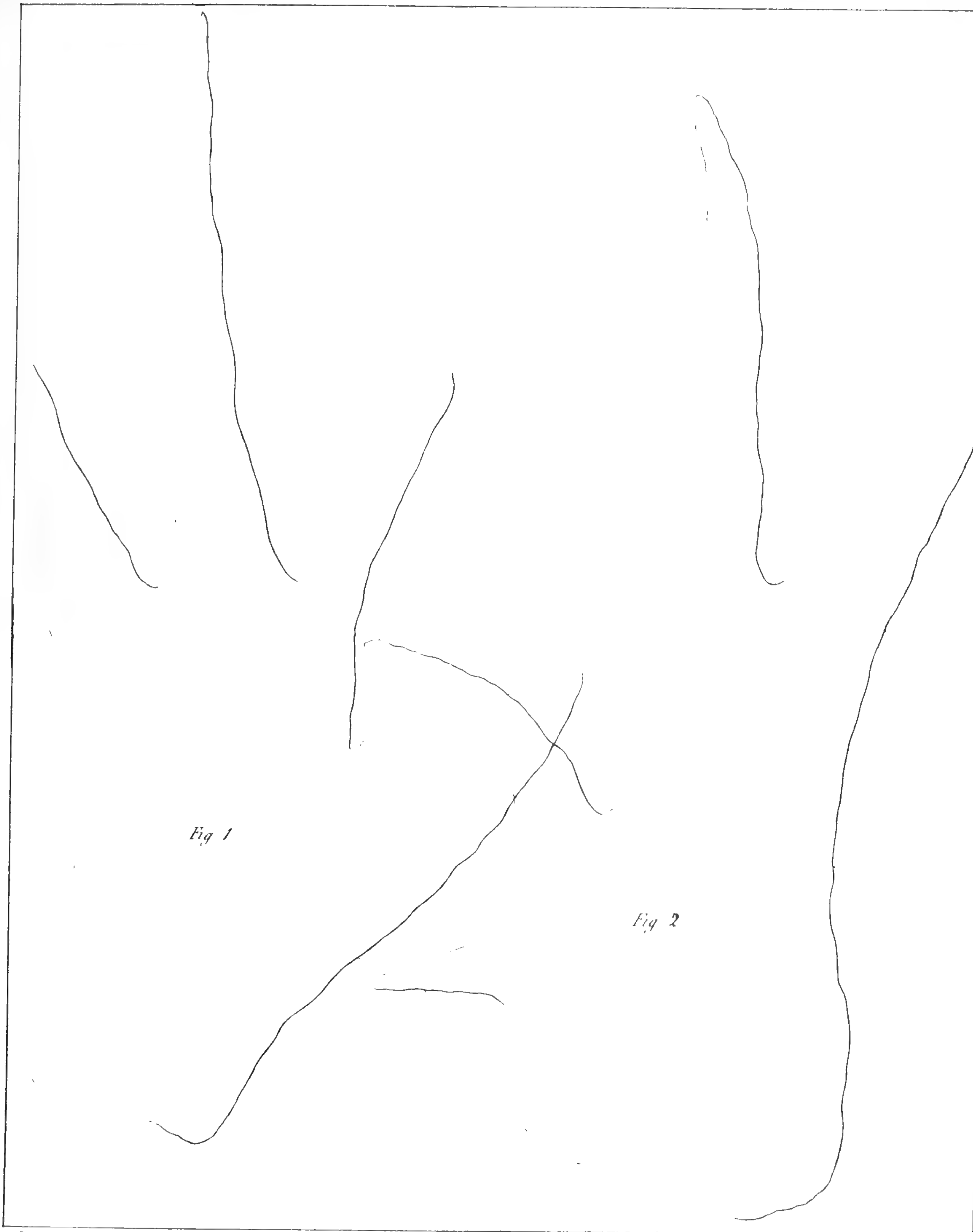


Fig. 2
Fig 1.
Fig. 4.
Fig 3.





Lith of G & W Endicott N. York



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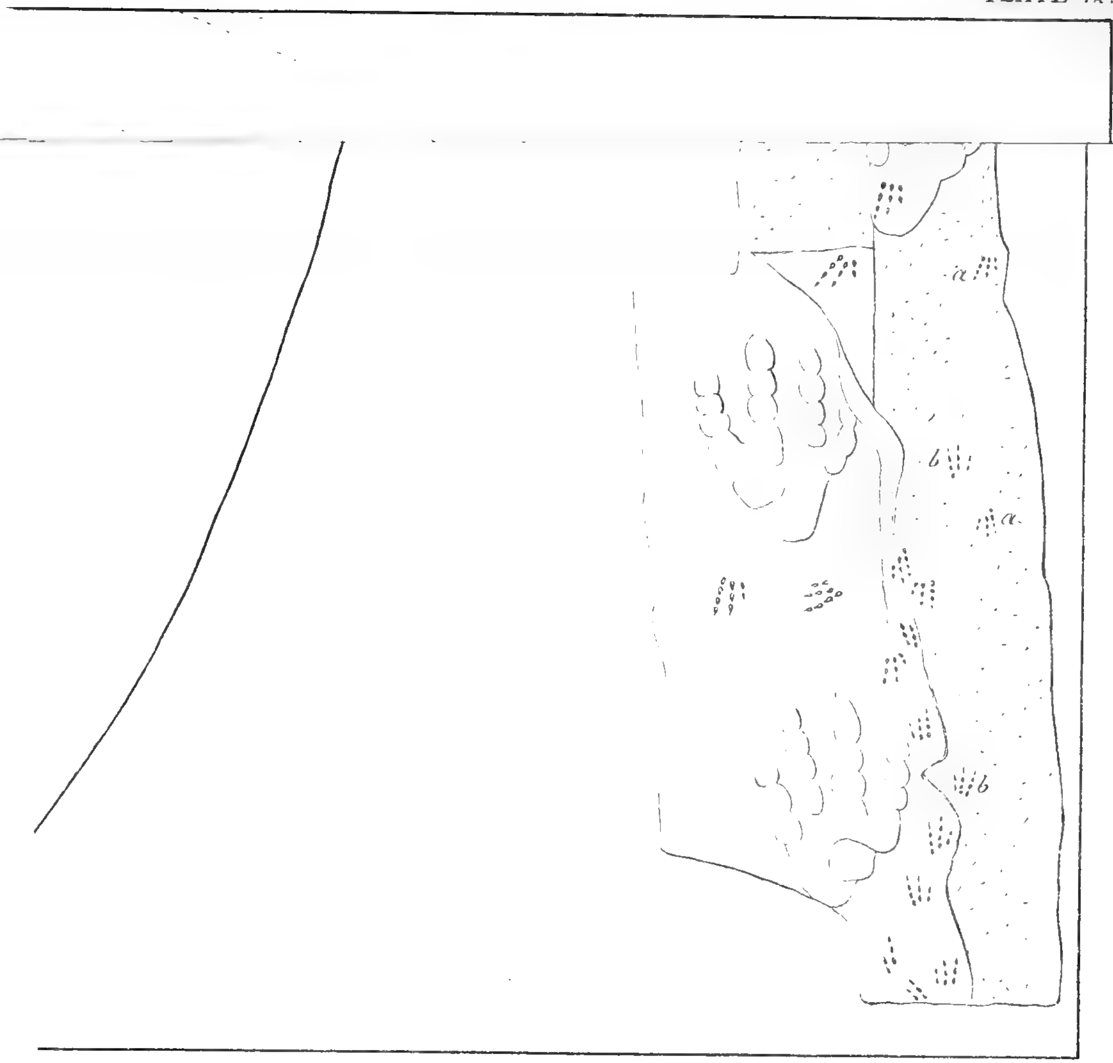
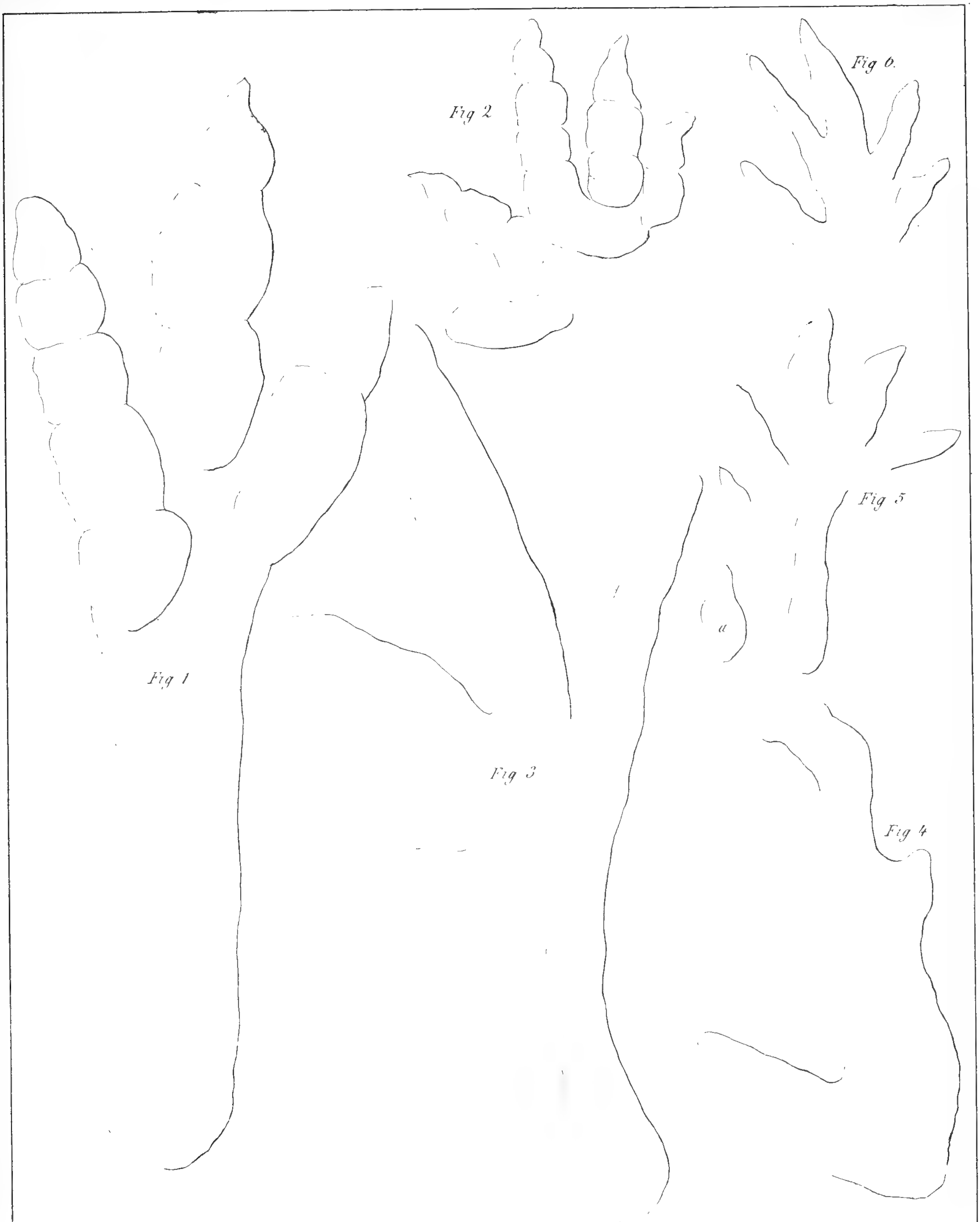
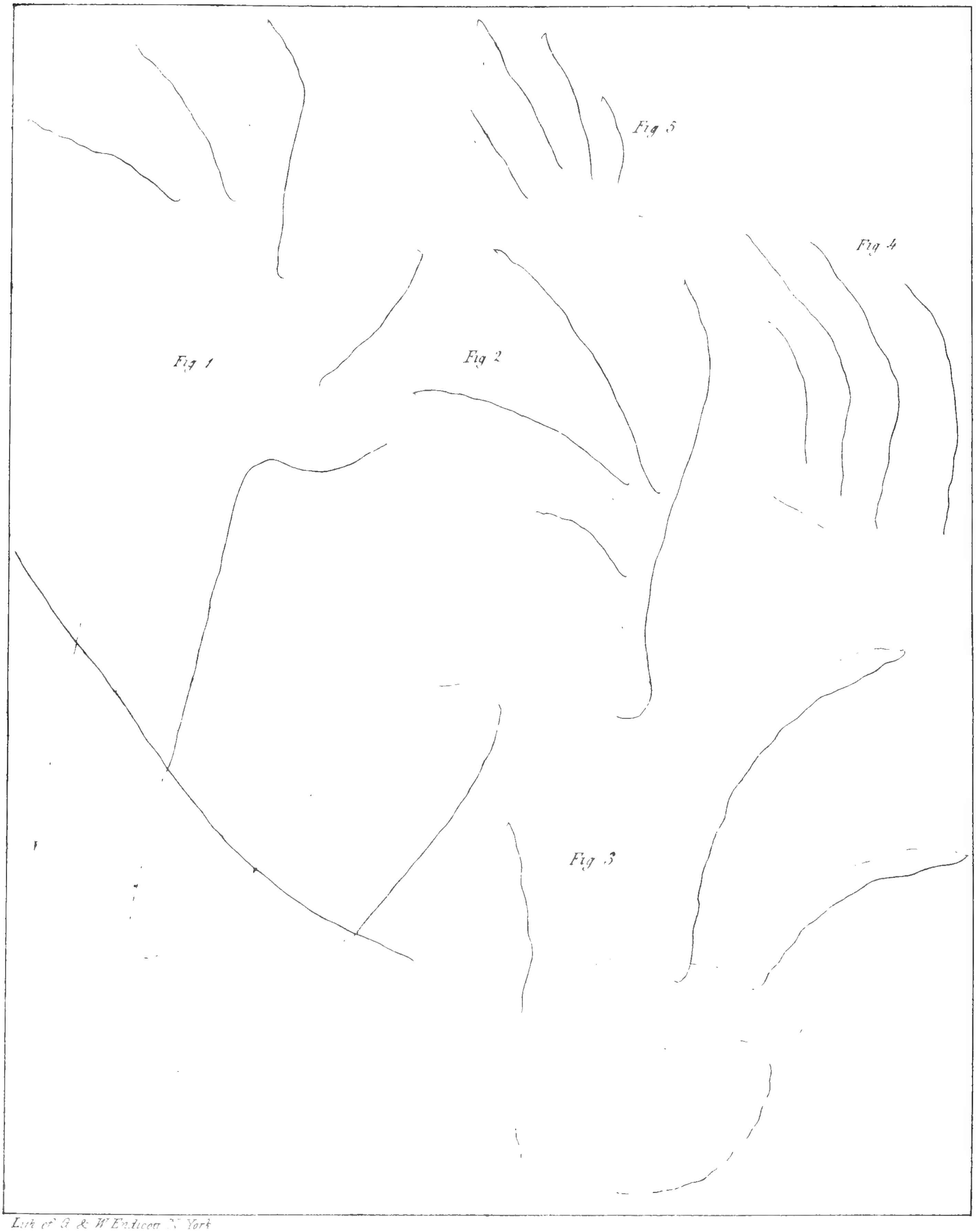

a
b
a
b



Lith of G. & W. Endicott New York



Lith of G. & W. Endicott N. York

Lith. of G & W. Endicott New York

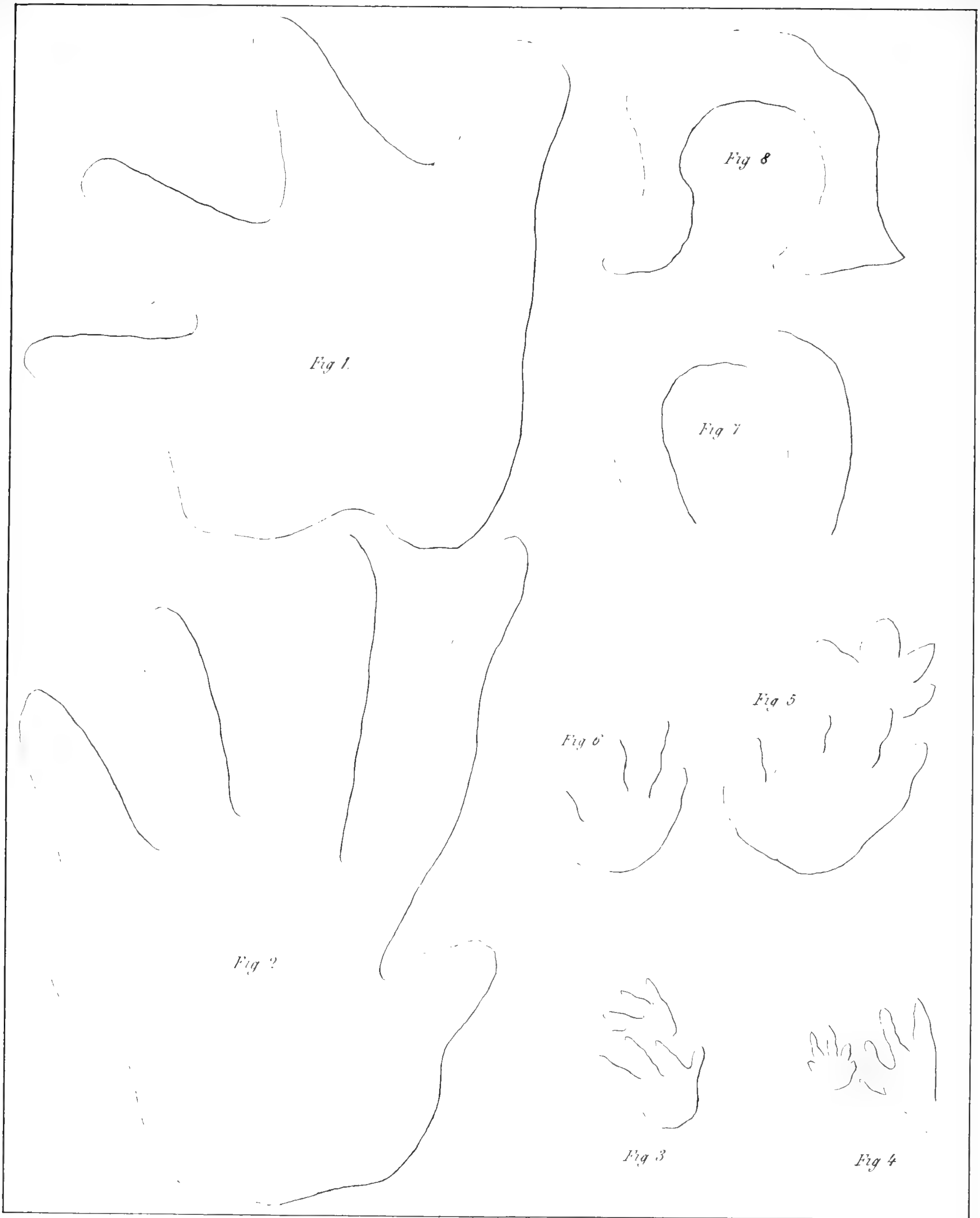


Fig 1.
Fig 2
Fig 3
Fig 4
Fig 5
Fig 6
Fig 7
Fig 8

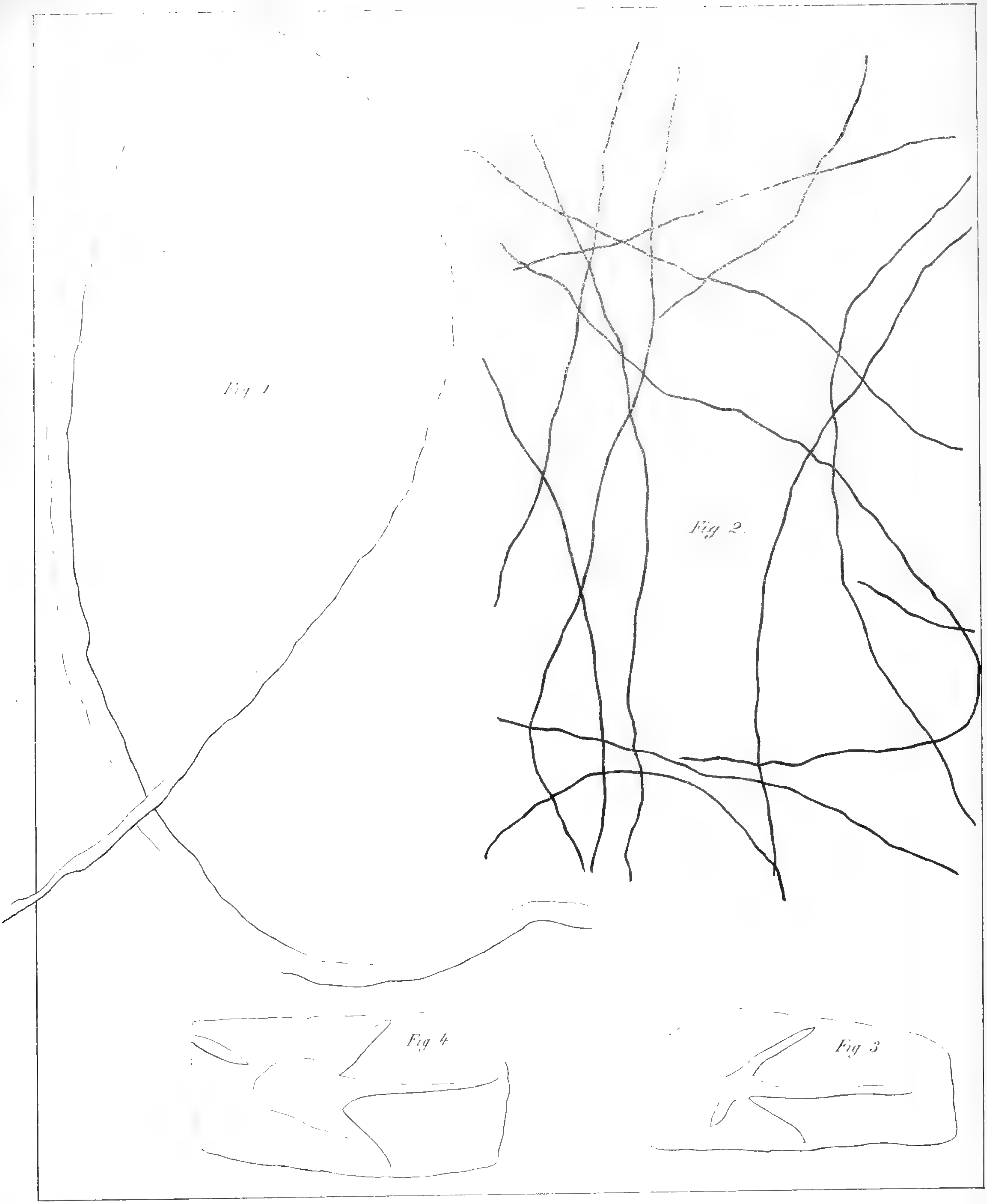


Fig 1
Fig 2.
Fig 4
Fig 3

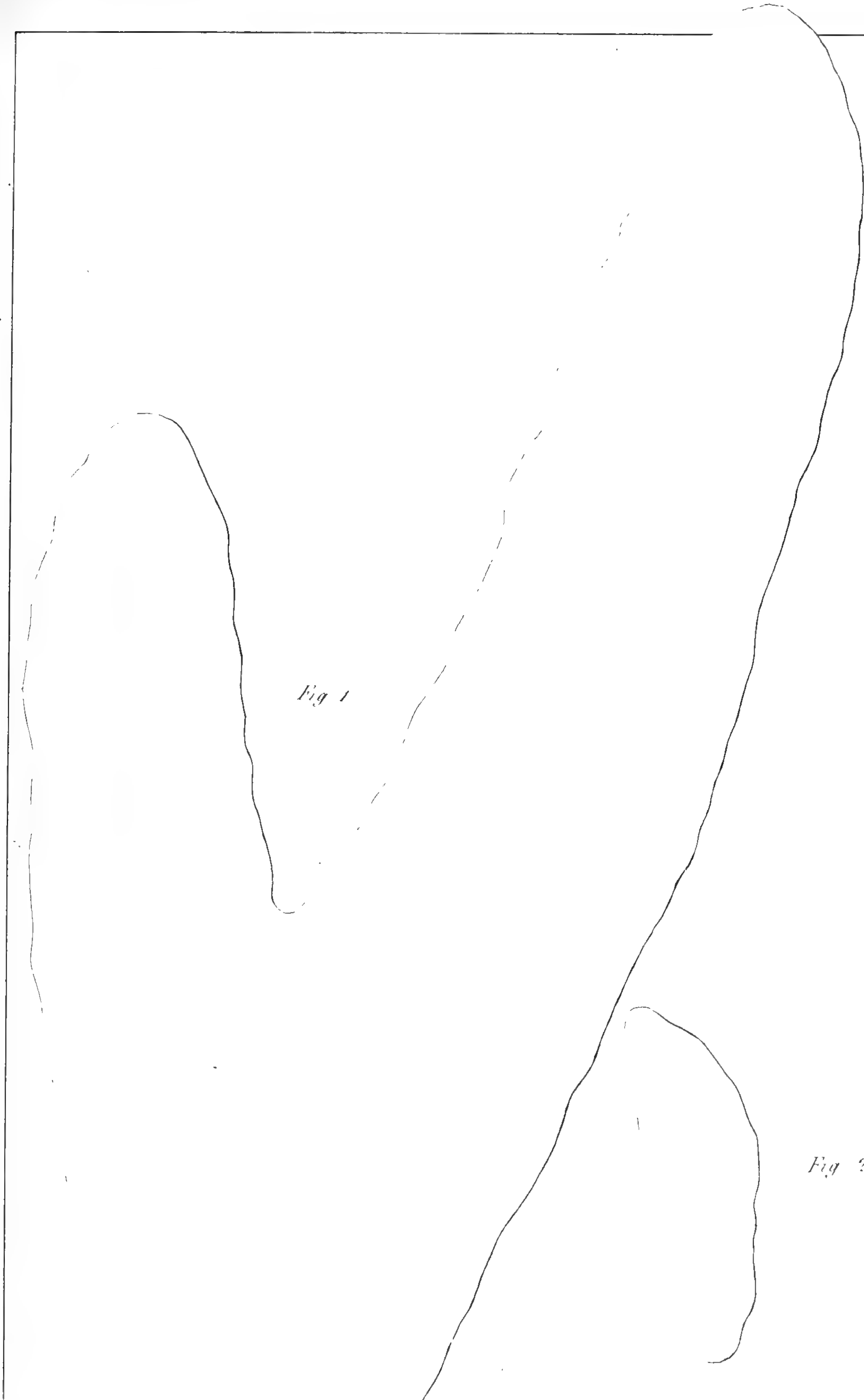


Fig 1

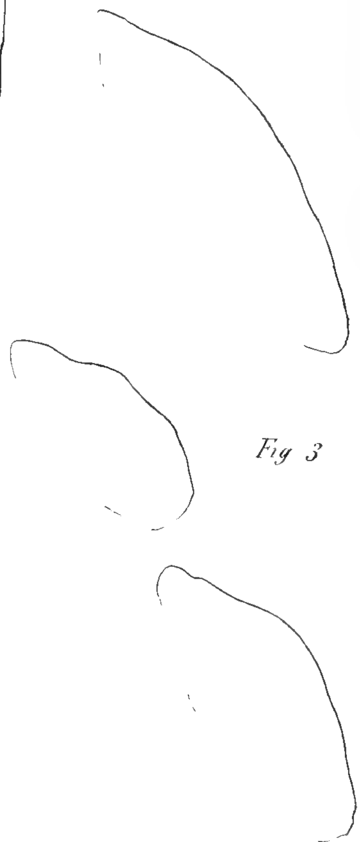


Fig 3

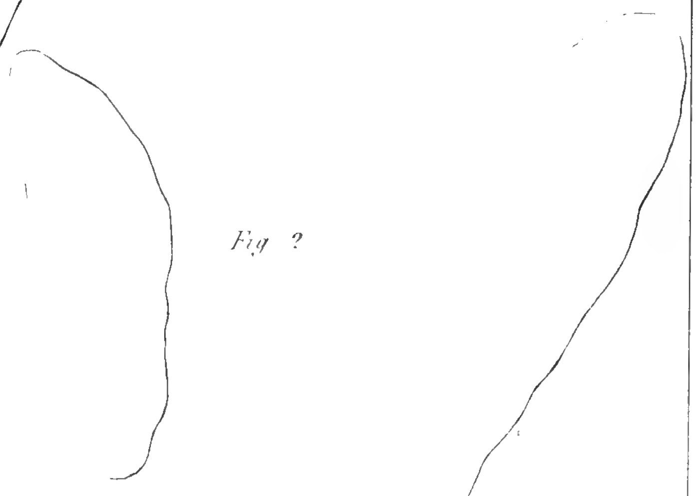
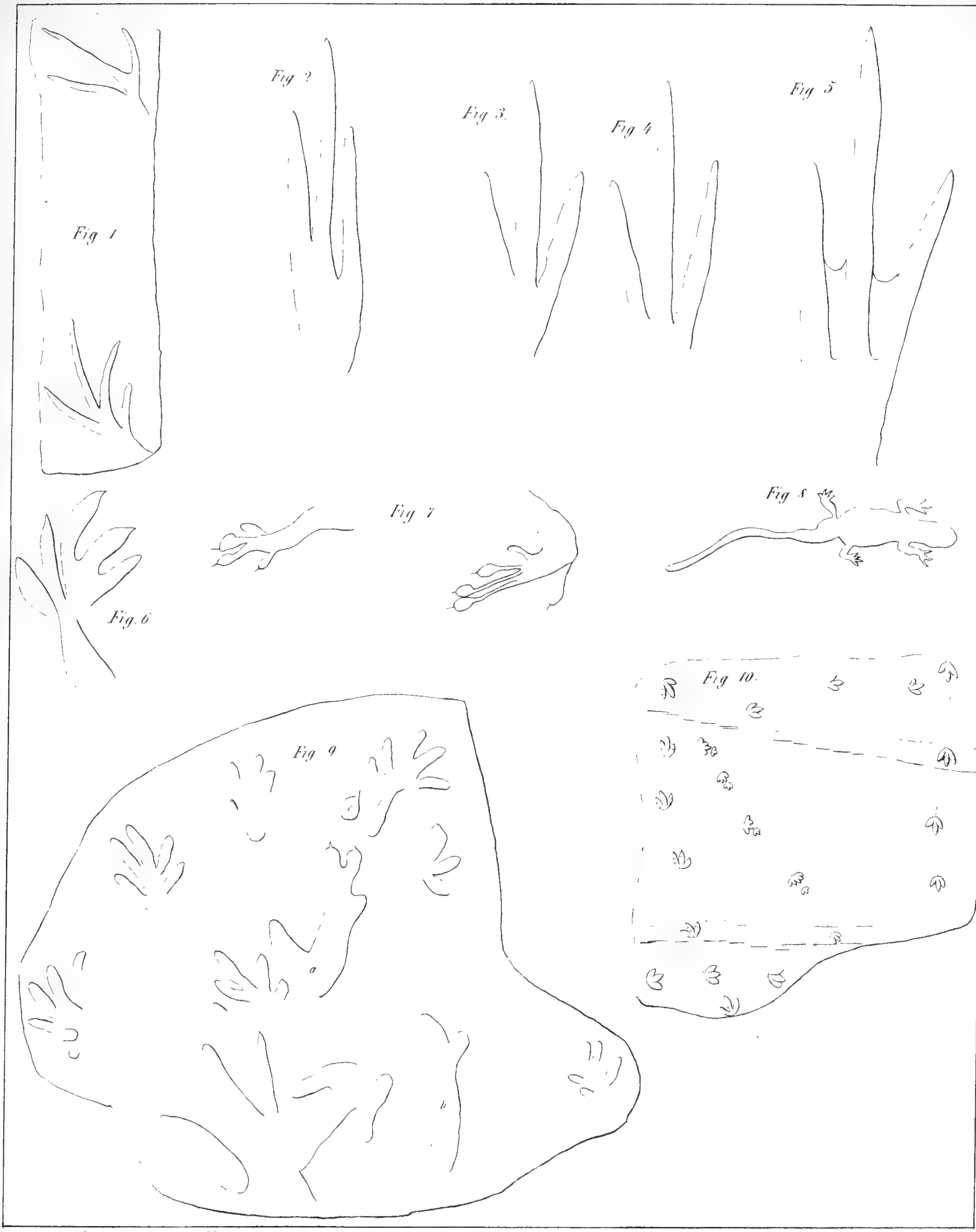
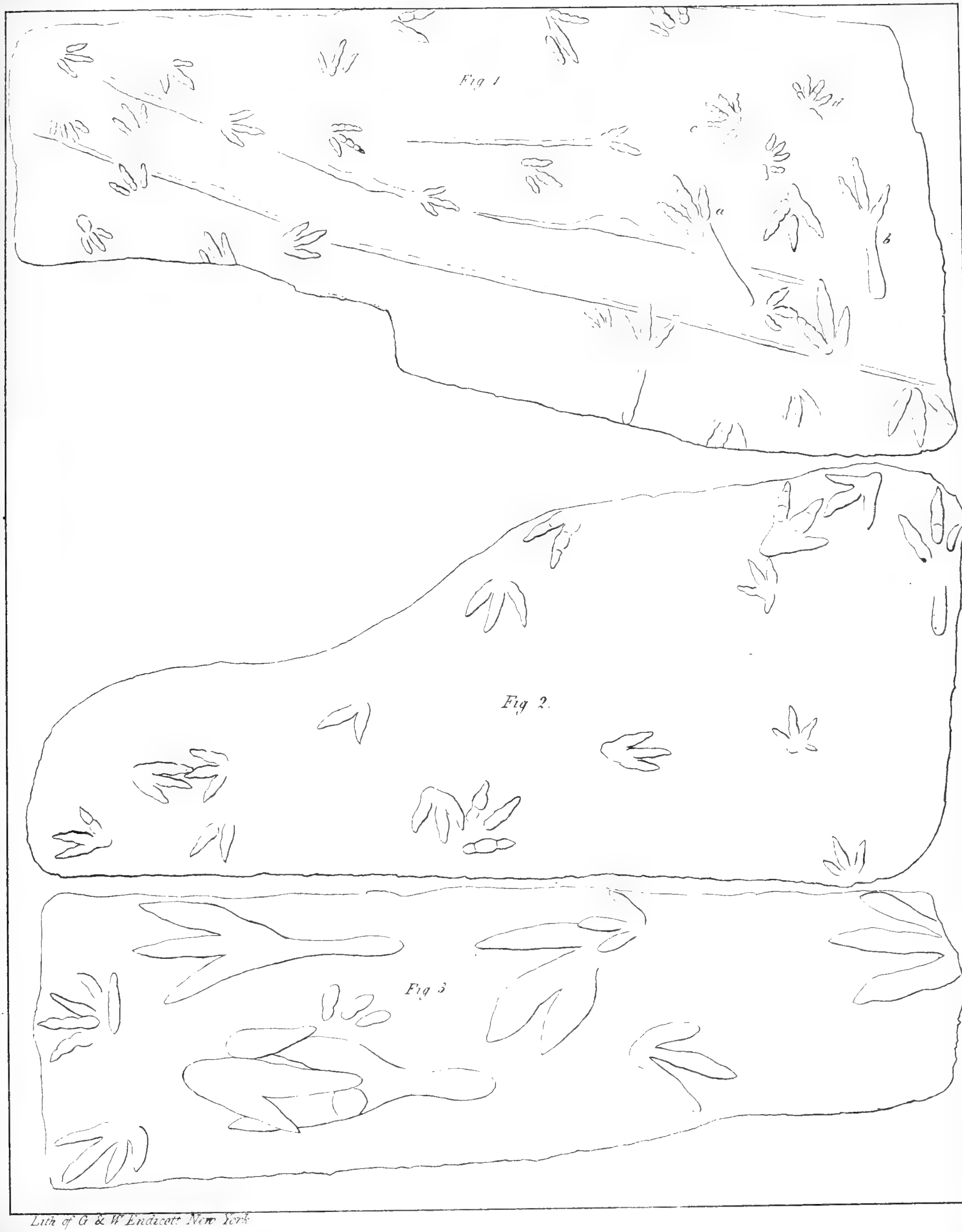


Fig 2


Fig 1
Fig 2
Fig 3
Fig 4
Fig 5
Fig 6
Fig 7

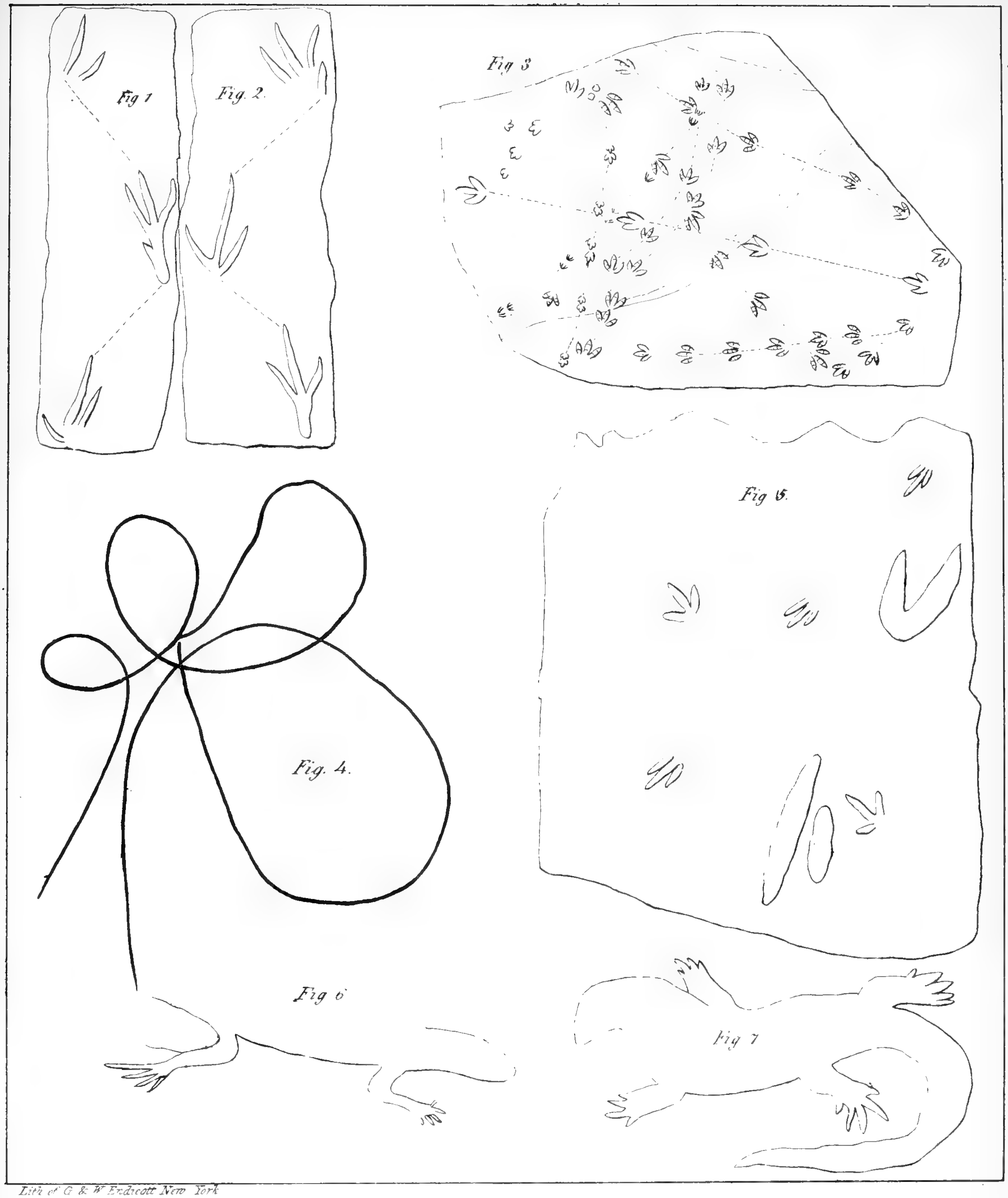


Lith of G & W Endicott New York

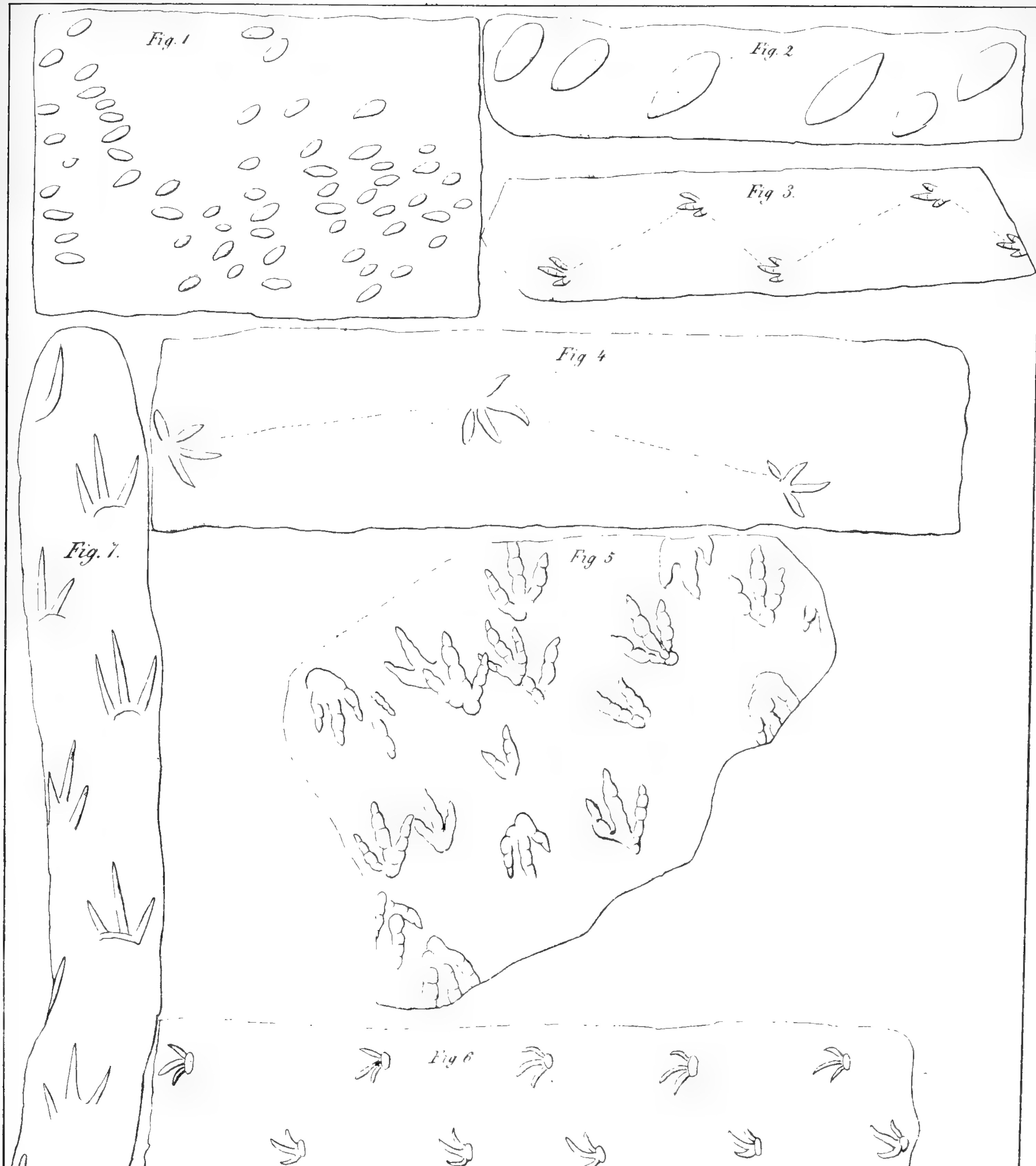


Lith of G & W Endicott New York

Lith. of G. & W. Endicott New York



Lith of G & W Endicott New York



Lith of G & W Endicott New York

VIII.

On Platygonus Compressus: a new Fossil Pachyderm.

By JOHN L. LE CONTE, M. D.

(*Communicated to the Academy, May 29th*, 1848.)

In the short notice of new fossil Mammalia, published in *Silliman's Journal* for January, 1848, I have given an account of the circumstances under which these bones were found, which are briefly these.

At a few miles distance from Galena, in Illinois, while sinking a shaft for the purpose of obtaining lead ore, a fissure was discovered fifty feet below the surface; this fissure was filled with an earthy deposit, containing much iron and lime, and imbedded in it were found many fragments of bone. A portion of these were preserved by the miners, and by good fortune found their way to the collection of Mr. Snyder, a merchant residing in Galena, and well known for his appreciation of natural science. By him some teeth were presented to me a few years ago, in order to determine the species of animals to which the bones belonged. On examination, these teeth were found very different from any heretofore observed, and it was at once evident that they appertained to one or more new genera. Notice of this fact was sent to Mr. Snyder, and permission was asked to examine the other mammalian fossils of his cab-

inet. Not only was the request granted, but, with the generosity of a scientific spirit, the entire collection was placed at my disposal, that it might be rendered more accessible to our comparative anatomists. Mr. Snyder has also promised to procure such other specimens as may be found in his vicinity. It is also hoped that in a short time casts of the bones already obtained will be ready for distribution to the learned societies of our country.

Among the specimens now in my possession were detected remains of the following animals: — *Platygonus compressus* (the subject of the present memoir), *Hyops depressifrons* (a new animal allied to *Dicotyles*), and a new species of *Procyon*. From another fissure were obtained teeth, indicating two other new genera, which are referred to in the notice quoted above.

We now proceed to the description of the separate bones of the first-named animal, commencing with the teeth.

Dentition.

By carefully picking away the cement which envelops the anterior part of the fragment (figs. 1, 2), a small external incisor was discovered: the distance of this tooth from the superior canine is given in the table of measurements at the end of the descriptive part of this memoir. The bone is so much mutilated, that it is impossible to determine whether there were two or three superior incisors on each side; although, from the affinities of the animal, there were doubtless three. In the form of the tooth there is nothing peculiar; it has a rounded mammillary crown, scarcely acute at the summit.

The superior canine (figs. 9 – 11) is very much compressed, pointed, and curved; the anterior edge almost sharp; the posterior acute and trenchant; the external face (fig. 9) slightly more con-

vex than the internal, and marked near the base of the enamelled portion with an acute, elevated line, which runs obliquely to the anterior edge, where it is met by a similar less elevated line belonging to the internal face (fig. 10); this latter line is acutely angulated at the base, and joins another elevated line which arises near the angle in the line defining the enamelled surface, and continues parallel to the anterior margin about half-way to the extremity, where it gradually vanishes. The anterior margin is worn into a very narrow surface, extending from *a* to the extremity, *b* (fig. 9). The inserted portion of the tooth is slightly sinuous on the anterior margin, and is marked with two very feeble grooves on the external surface; the space between these grooves is rather more convex than the adjoining parts. At *c* (fig. 9), the fang is slightly contracted.

The only teeth I have seen figured, which can be compared with the present specimen, are the canines of the genus *Machairodus*, which are, however, distinguished by the curiously serrate edges, and the absence of the oblique basal lines so characteristic of *Platygonus*.

The superior premolars are shown in figs. 12 and 13 (*p*. 3, *p*. 4). That *p*. 4 (fig. 13) must be considered a premolar is evident from an inspection of fig. 2, in which are seen three premolars in place, while the socket of the fourth is quite distinct. In my notice of this genus in *Silliman's Journal* (*loc. cit.* p. 103), it is stated that there are but three premolars; I had not then cleaned away the cement in which the socket (*p*. 4, fig. 2) was concealed; I also considered *m*. 1 (fig. 13) as the penultimate molar, but on comparing it with the tooth anterior to fig. 13′, it shows minute differences, which will be detailed below.

The first premolar, right side, *p*. 1 (fig. 12), is triangular, with

rounded angles; the crown rises externally into a subquadrangular tubercle, which is impressed anteriorly and posteriorly; the external surface of this elevation is continuous with the margin of the tooth, while on the other sides it is surrounded by a broad cingulum, which is wider posteriorly. In the younger individual (fig. 2), this cingulum rises into an acute ridge, which is foveate on the anterior and interior portions.

The second premolar, *p.* 2 (figs. 2 and 12), is subtriangular, slightly transverse, with a large transverse elevation, and an anterior and posterior basal margin, which nearly unite on the external face in the younger specimen. The transverse elevation is divided into two cusps, by a deep antero-posterior incision, and the posterior basal margin, at the external angle, rises into a small tubercle.

The third premolar, left side, *p.* 3 (figs 2 and 13), is subquadrate, transverse, and a little narrowed internally; it is furnished with transverse elevation and basal margins, as in the preceding, but they are more strongly marked: the external pyramid is slightly produced anteriorly, and descends almost to the margin of the tooth.

The fourth premolar, left side, *p.* 4 (fig. 13), is similar to the molar next described in all its sculpture, but is smaller, and the shape slightly different; the internal margin is scarcely emarginate, and the anterior margin is not oblique, but very slightly sinuous, for the curve of the 3d premolar.

The first molar, *m.* 1 (fig. 13), is quadrate, with two large transverse elevations, each of which is divided into two pyramids, or cusps, the external being smaller; the internal posterior pyramid is produced obliquely outwards to the posterior margin; the internal anterior pyramid sends a similar but smaller prolongation to the anterior margin. The basal cingulum is well developed on the anterior, external, and posterior margins, except where it is sub-

interrupted by the prolongation of the posterior internal pyramid. There is no internal basal margin, except at the expansion of the valley between the ridges. This valley is deeper at the extremities than in the middle, where it is penetrated by an anterior prolongation of the posterior internal pyramid. The anterior margin of this tooth is oblique, the external angle being prominent, and more rounded than the internal. This proves the existence of a slight angle at the junction of the molar with the premolar series, to accommodate the position of the teeth to the compressed form of the head anterior to the molars. The line of insertion of the inferior molars follows the same course, and will be found hereafter to strengthen this deduction.

The second molar is quite similar to the first, but is regularly quadrate, the anterior margin not being oblique ; the figure and description already given will serve to identify it perfectly. It may be stated that this tooth was found in juxtaposition with the third molar ; the whole series of that side were imbedded in a thin mass of very hard cement, but the roots having entirely decayed, the specimens were so fragile, that, in endeavouring to expose the crowns, the first molar was entirely destroyed ; for this reason, the third and fourth premolars, and first molar, are figured from an older and slightly larger specimen than the one which furnished the third molar.

The third molar, *m.* 3 (fig. 13′), also of the left side, is longer than wide, slightly narrowed behind, emarginate on the sides, with the anterior external angle a little prominent, and more suddenly rounded; the sculpture is similar to that of the first and second molars, but in addition, the posterior basal cingulum rises into a small uneven cusp, connected with the internal pyramid of the posterior eminence: on the externo-posterior face of this pyramid a trapezoidal plane is developed by wearing, extending to the basal cusp.

All these teeth, by wearing, lose the separation between the cusps of the transverse elevations, which thus become broad and straight ridges, having the extremities a little more elevated than the middle.

In the fragment of the lower maxilla, only the second and third molars are preserved. There are remains of the first molar and the posterior premolar, but not sufficient for description.

The second molar, *m.* 2 (fig. 7), is quadrangular, with rounded extremities and somewhat emarginate sides; it presents two large transverse ridges separated by a deep valley; there is a very slight anterior and posterior basal margin, more elevated in the middle; the valley has a very indistinct margin externally, and at that place the anterior lobe rises suddenly, so as to form a very well defined right angle with the margin; there is another angle, but less sharply defined, between the same margin and the posterior lobe.

The third molar, *m.* 3 (fig. 7), is elongated, narrowed and rounded posteriorly, scarcely emarginate on the sides; it has two large transverse lobes, as in the preceding, a very obsolete anterior basal margin, and a large posterior undivided lobe, acute at the top, and almost as much elevated as the two principal lobes. This lobe is separated from the second lobe by a valley, acute at the bottom, and a little deeper internally than externally; into which fits the small posterior cusp of the third superior molar. The valley separating the second from the first lobe is wide, and deeper internally. At the outer part it has a small horizontal triangular face (*a*); and the external margin of this face forms with the anterior lobe a very distinct obtuse angle: with the second lobe it forms a less distinct right angle. It is to be observed that the internal extremities of the transverse lobes of these lower molars are more elevated than the external parts.

These two molars are inserted in a line slightly oblique outwards with reference to the long axis of the bone; the first molar continues this line, but the roots of the premolar, as well as a slight flexure in the bone, indicate that the line of insertion there changes its direction by bending inwards, to a degree which would probably make it parallel with the line of the opposite side. This agrees with the inference from the form of the first superior molar, and also with the shape of the cranium hereafter described. The dentition as far as determined is, —

$$\text{inc. } \frac{3?-3?}{?};\ \text{can. } \frac{1-1}{1-1};\ \text{prem. } \frac{4-4}{?};\ \text{mol. } \frac{3-3}{3-3};$$

which agrees with the general formula for the *Tapiroidea;* to which group of Pachyderms the teeth, from their separate characters, would most naturally be referred.

The measurements of the teeth described, in English inches, are as follows: —

	Length.	Breadth.		Length.	Breadth.
1st superior premolar,	.35	.32	1st inferior molar,	.46	?
2d " "	.41	.47	2d " "	.60	47
3d " "	.43	.50	3d " "	.78	.45
4th id. (from larger spec.),	.50	.46	*Dimensions of superior canine.*		
1st molar (larger spec.),	.65	·55	Length of exserted part,		1.59
2d molar,	.61	.55	Breadth of lateral surfaces at base of exserted portion,		.50
3d molar,	.77				
(Breadth anteriorly, 62; post., .56.)			Thickness of tooth,		.30

Bones of the Head.

The portions of the skull obtained are, — the anterior part of the upper jaw; the posterior part of the os frontis; part of one os malarum, with the os lachrymale; portions of the palatal plate of superior maxilla; and the posterior part of the inferior maxilla.

The first-mentioned fragment is represented, fig. 1, side view;

fig. 2, base view; fig. 5, *A*, top view. From it we learn that the head was very narrow, and compressed on the sides; the canines were concealed by the lips, and projected forwards downwards, and a little outwards. The malar plate of the superior maxilla is expanded very obliquely outwards, and above it is a wide but shallow groove (*a*, *a*, fig. 1), which is parallel with the superior suture, and vanishes opposite the first premolar.

Above the superior canine, the bone swells out into a somewhat acute prominence, from which a concavity (*f*, *A*, fig. 5), expanding as it advances, looking outwards and a little forwards, runs towards the incisor. The suture of the intermaxillary bone passes upwards and backwards very close to the canine, and almost in contact with the anterior wall of its socket.

The ossa nasi are very convex from side to side, forming a semicircular arch; they are also very slightly arched antero-posteriorly. About the region of the canines, the skull expands a little, the lateral surfaces being there flattened and oblique. From a small fragment (fig. 3), containing the root of the first premolar, it will be seen that an elevated line originates opposite that tooth, and is lost before reaching the canine; this line is parallel to the alveolar margin; immediately above it, and a little anterior to the first premolar, is a small foramen (*a*, fig. 3). Below the elevated line is a deep longitudinal concavity, oblique downwards, separated from the palatal plate by a second elevated line. The palatal plate is seen in fig. 2; it is concave transversely, with flattened sides; by picking away the cement at the anterior part of the fragment, it appeared that this concavity becomes more narrow anteriorly, at the same time increasing in depth, until it assumes the form of a medial groove. On each side are the remains of a deep groove (*a*, *a*, fig. 2); and by reference to the palatal part of the small fragment

just mentioned, this groove is seen to be double, the external groove being in contact with the alveolar margin; the interior of these grooves is deeper, and perforates the plate immediately opposite the first premolar. Another fragment containing molars shows a flattened surface, rough with longitudinal grooves and elevations towards the side, as if worm-eaten.

The os frontis is seen in fig. 4. The posterior contour is rounded almost in the arc of a circle; the posterior edge is bevelled off very obliquely, and striate for the adaptation of the ossa parietalia, which have not been obtained. The approximation of the postorbital processes is remarkable; they project laterally, having scarcely any tendency downwards; the superior surface of the bone is much flattened, being scarcely more elevated in the middle than at the sides.

Fig. 5 represents the parts already described, in their relative position, with the addition of (*B*) the malar bone and part of the lachrymal. The external surface of these bones is flat, and looks forwards and outwards, but not at all upwards; the posterior orbital process (*a*) is very long, acute, and bent inwards at the point; at *d* is an indication of a wide, shallow groove; *b* is the lachrymal tubercle, more elevated than in *Dicotyles*, and placed on the margin of the orbit; anterior to this the surface looks directly upwards; at the base of the lachrymal tubercle is (*c*) a groove, in which are placed the lachrymal; anterior to this is (*e*) a slight concavity. In the position of the groove and foramina with reference to the tubercle, a striking difference will be observed between this animal and its allies; the orbital plate is behind the tubercle, and looks inwards and backwards, the groove and foramina being altogether external. In *Dicotyles*, the orbital plate looks directly backwards, and the foramina are situated internally. In *Tapirus* (ac-

cording to Cuvier), the same foramina are on the edge of the orbit. The fragment of malar and lachrymal bones is represented in a side view (fig. 6), to show the flatness of the external surface, and also a small foramen; the other parts are lettered as above.

Fig. 7 is the lower jaw. It is very deep; the articular surface is placed obliquely, and formed as in *Sus* and *Dicotyles;* but the anterior margin is less prominent from the neck of the condyle at its external part; there is also a small external fossa (*a*, fig. 7), which does not appear in the animals just mentioned. The line from the condyle to the posterior molar is three fourths of an inch longer than in *Dicotyles torquatus*, and passes more obliquely inwards; which corresponds with the great posterior expansion mentioned in describing the cranium. Below the molars the bone swells out slightly, but not so much as in *Dicotyles;* the inferior margin is rounded, and but little attenuated: it is deeply concave in a longitudinal direction; this form is caused by the expansion of the angle of the jaw. The expansion commences at a point immediately below the anterior lobe of the posterior molar; it does not extend backwards to form a process or hook, as in *Carnivora* and *Rodentia;* nor does it interrupt the slight but regular concavity of the posterior margin, which is thin, and destitute of any prominent lines. The expanded part is very concave on the outer surface; the inferior margin is rounded, as in the figure, and projects far outwards, especially anteriorly.* Towards the fractured end the bone is expanded, and has a large cavity for the reception of a canine (fig. 8); but as this cavity is filled with the same hard cement which envelops many of the specimens, it is impossible to judge of

* The perspective of this part of the figure is not good; the anterior part of the expansion (towards the dotted line) should be in higher relief.

the form of the root of the canine. The internal surface of the bone is also concealed by cement.

Bones of the Trunk.

A dorsal vertebra is represented in figs. 14–16. The body is very much compressed inferiorly, with a sharp prominent middle ridge; the anterior surface is concave, the posterior convex; the peculiarities of the bone are better expressed in the figure than they can be by any description.

A lumbar vertebra (figs. 17, 18) has the body still more concave on the sides, and still more compressed inferiorly, the elevated line rising quite suddenly, and being very prominent (*p*), the posterior face is concave, and looks a little upwards; on the side of the body, at the posterior part, is (*a*) an obtusely elevated line, running obliquely upwards; anterior to this is a small tubercle (*b*); about the middle, and at the base of the medial ridge, is (*c*) a small foramen; and a small but deep fossa (*d*) is found close to the base of the transverse process.

Os innominatum has the ilium inferiorly narrow and compressed; above the acetabulum, but near its margin, are two fossæ, which extend upwards and shortly vanish; the posterior of these is narrowed about its middle by an elevation proceeding from its posterior lip. The external surface of the ischium below the acetabulum is free from elevations, and seems to be scarcely concave; the posterior edge is thin and compressed. The bone is so imperfect, that a figute would be of little value.

Bones of the Extremities.

The humerus (figs. 19, 20, bone of the right side), of which the lower part is preserved, is pierced by a large foramen. The lower

head is oblique inwards; the articular surface is regularly concave behind; anteriorly it has two pulley-shaped grooves, the interior being broader, but not shallower, than the exterior; the intervening ridge is obtusely rounded, broad, and as much elevated as the sides; a transverse depression separates the articular surface from the edge of the foramen; the internal condyle is fractured, the external is flatly truncate anteriorly, with a groove continuous with the transverse depression just mentioned; this groove runs downwards, and vanishes towards the lower edge of the condyle. Posteriorly, as shown by another much mutilated specimen, this condyle is marked with two small grooves, which run in the direction of the interior or narrow pulley-shaped surface; but this part being covered by cement, I know not whether they meet the articular surface. Other peculiarities will be better seen in the figure than expressed in description. Immediately above the groove, on the outer truncate surface of the condyle, the bone is dilated, and then regularly contracted to the shaft. The cavity for the olecranon is very deep.

The bone of the cubitus (fig. 21, left side) is comparatively thick, and much bent, the concavity of the curve looking backwards. The radius and ulna are so fused together as to be scarcely distinguishable. The shaft is subtriangular, the external edge being acute and much compressed; the anterior and internal edges are indistinct. The anterior face is broadly concave, adjacent to the compressed edge. The superior head of the bone is furnished with articular surfaces corresponding to those of the humerus; they are separated by two elevations extending from before backwards. The internal surface looks inwards and upwards, and is equal to the middle one; the external surface looks outwards and upwards; behind the middle surface, at the base of the olecranon, is a deep concavity, separated at the bottom into three unequal parts: dividing

the internal concave surface, at the base of the olecranon, is a narrow groove, with a depression behind the interior ridge. The lower extremity is dilated, so that the internal edge of the shaft is rendered concave; anteriorly this extremity is convex, posteriorly flat; the styloid process (*a*) is short, and immediately above it is a slight concavity. The lower articular surfaces are shown in fig. 22, *a* being the styloid process. The other faces for the scaphoid, semilunar and cuneiform, are so well defined as scarcely to need description; and the more so, because, from the meagreness of our museums, I have not been able to make comparison with the corresponding parts of other *Ungulata*. There is very little resemblance between the present specimen and the antebrachium of a hog; the resemblance to a horse is much more decided, but the lower articular surfaces are quite different in form.

Os calcis. — The bone of the left side was found with both extremities fractured; the shaft flattened, with rounded edges: the inferior margin (concave in *Sus*) is perfectly straight; the superior is scarcely concave; the large process for articulation, with the astragalus, is much thickened inferiorly, and marked with a slight groove. The articular surface is scarcely longer than wide, slightly concave; superiorly it is scarcely prominent beyond the margin of the shaft: the hollow below this process is regularly narrowed, but there is no fossa superiorly between the articular face and the anterior part of the bone. In the common hog there is a very distinct fossa.

Os cuboides. — The bone of the left side is shown in fig. 25, external view; and fig. 26, internal view. The surface for the calcaneum is long and sinuous, as in *Sus*, but the depression (*a*) is much deeper; between this surface and that for the astragalus is (*b*) a deep groove, rounded at the extremity, extending almost to the concavity (*a*). The astragalian surface is deeply concave, and

looks backwards, but not at all inwards; its length is five times greater than its breadth. Anteriorly the groove (*c*) is very deep; the face for the metatarsal (*d*) is subtriangular, with rounded angles, the internal angle being more produced; the inner side of this articular face is slightly emarginate, but there is no fovea under the emargination, as in *Sus*: the prominence (*h*) is furnished with a narrow, oblique, articular face, for a rudimentary external metatarsal. Internally is (*e*) an oblong tubercle, with an acute edge; the posterior face of this tubercle is articular for the scaphoides; at the inferior part of this surface is (*f*) a long irregular articular surface, also for the scaphoides; it is emarginate superiorly, with a depression at *g*. The superior surface of the bone, owing to the extension of the calcaneal face in an anterior direction, is shaped somewhat like the small Greek π, and has an elevated line parallel to the anterior margin.

The medial metatarsal of the right side (figs. 23, 24) has a triangular shaft, the external and posterior faces flattened, and meeting almost perpendicularly, the other face being rounded almost in a quadrant; the line between the posterior and internal or curved face is strongly marked above, but fades out at *g* (fig. 23); the line between the posterior and internal (*a*, *a*) is more strong below, but becomes obsolete above, where it tends towards the anterior process (*e*, *e*); the anterior edge (*f*) is well marked for the whole length of the bone. The upper extremity is articular for the large cuneiform, with a small surface at the internal angle for the second cuneiform; the line in which these unite is very indistinct, and commences at the cusp (*d*). The large articular face is concave towards the antero-internal part, and there extends much lower on the bone (*vid.* fig. 24). The anterior angle of the upper extremity of the bone is produced into a curved truncate process, furnished with two articular facets (*e*, *e'*). The posterior internal angle is

also furnished with a small lateral articular face (b). On the posterior face of the bone, near the extremity, are two deep fossæ (c, c', fig. 23), provided with articular facets for the internal metatarsal, which is thus shown to have been posterior, but by no means rudimentary. The lower apophysis is unfortunately wanting; but what remains is much longer and more slender than the corresponding part of *Sus Scrofa*, and shows plainly that the comparatively slender form of the head and humerus was continued even to the feet.

Measurements of the Fragments.

Cranium.

	Inches.
Incisor to centre of canine (figs. 1 and 2),	1.20
Incisor to anterior edge of 1st premolar,	3.43
Incisor to posterior edge of 3d premolar,	4.40
Centre of canine to anterior edge of 1st premolar,	2.10
Distance between broken extremities of canines,	2.05
Height from palatal plate, opposite 1st premolar, to top of nasal arch,	2.43
Transverse diameter at same point,	1.35
Transverse distance between internal margins of 2d premolar (calculated),	1.00
Transverse distance between postorbital processes of os frontis,	3.20
From last line to middle of posterior curve of external surface (being the versed sine of the curve),	.97

Inferior maxilla.

	Inches.
Exterior margin of condyle to posterior angle of 3d molar,	2.80
Do. to anterior edge of 2d molar,	4.00
Depth of jaw at posterior lobe of 1st molar,	2.20
Do. at anterior lobe of 3d molar,	3.00
Depth of curve of inferior margin (measured from a horizontal line),	1.35
Depth of concavity of external surface,	.30

Extremities.

All the figures are made of the natural size, so that only the following measurements are necessary: —

Length of metatarsal (fig. 23),	2.40
Breadth of surface (a, f) superiorly,	.30
Do. inferiorly,	.60
Anterior edge of e to posterior of b,	.55
Point of process (e, e') to cusp (d),	.60

Conclusions.

From the foregoing account, it will be seen that our animal presents an assemblage of characters not found in any other genus, fossil or recent. From the form of the teeth, and the concealment of the canines, it evidently tends towards the *Tapiroids*, and more especially towards *Sophiodon*, and it should be numbered among the aberrant forms of that group; nevertheless, it differs from both *Tapirus* and *Sophiodon*, in the very compressed and trenchant form of the canines. The extreme narrowness of the worn face of the superior canine, together with the oblique position of the tooth, indicates a decussation with another narrow and pointed tooth of the inferior maxilla. This structure is well adapted for piercing and cutting soft substances, and manifests a strongly carnivorous habit. This inference is not borne out by the form of the premolars, but it must be remembered that the cutting form of those teeth is always more developed in the lower jaw; the structure of the upper premolars in *Dicotyles* is very similar to that existing in the present genus. The absence, however, of accessary tubercles in the molars shows the suiline affinities indicated by some other bones to have been quite feeble.

The fragments of the cranium lead us to infer that that portion was very much compressed laterally, with an anterior and posterior expansion, the latter being much greater. The arch of the nasal bones being complete, and extending far forwards, it is obvious that the movable snout (if any) was extremely short. The malar bones descended almost perpendicularly, looking forwards and outwards, while the remains of the orbit of the eye show that organ to have directed outwards and a little upwards. The flatness of the os frontis and the approximation of the eyes continue to the upper

and posterior parts of the cranium the peculiar narrowness which gives to the anterior portion such an extraordinary appearance. The singular position of the lachrymal foramina, external to the orbit, and anterior to the lachrymal tubercle, as well as the upward aspect of that part of the bone (almost perpendicular to the external face), will also be found worthy of remark.

In the lower jaw we observe farther evidence of this great compression, while the inferior expansion of the bone around the angle is observed only in the hippopotamus among existing pachydermata, and in that genus on a much less extensive scale. As the posterior margin of the maxilla is somewhat concave, this expansion must be considered as a much modified development of the ferine type, in which the expansion is continued directly backwards.

From an attentive study of the os cuboides and metatarsal, it will be seen that *Platygonus* combines the characters of the *Isodactyle* with those of the *Anisodactyle Ungulata*, retaining at the same time the essential characters of the latter. It appears to have had three well-developed toes, with a rudimentary external toe; the relation existing between the astragalian and calcaneal faces of the cuboides is different from any that I can find described. But being obliged to deduce these analogies from drawings and descriptions, without reference to specimens, the observations must necessarily be imperfect, and I am therefore unable to draw the inferences which would become obvious to a student having access to the great museums of Europe.

The study of the bone of the antebrachium is more satisfactory: the radius and ulna are firmly anchylosed throughout their whole length, and the inferior surfaces resemble closely those of ruminants, without being identical; the two elevated lines separating

the articular faces for the scaphoides, semilunare, and cuneiforme are very oblique, as in the group just mentioned. The double groove of the lower articular surface of the humerus also shows an approach towards the ruminant and suiline tribes, while the large foramen of the coronoid cavity is a character found in but few species, and, with the very oblique external contour, serves very well to distinguish the bone of the present genus, when the articular part is destroyed. The obliquity of the inferior head, with reference to the long axis of the bone, is much greater than in *Sus;* and the external pulley very much deeper than in *Sus* or any ruminant.

In a future memoir, on the *Hyops depressifrons*, a suiline animal, the remains of which were found in the same locality, will be detailed my reasons for referring to the genus with trenchant canines the fragment of calcaneum and metatarsal bones described in the preceding pages.

PLATE 1.

Fig 1.

Fig 3

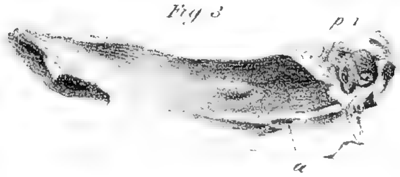
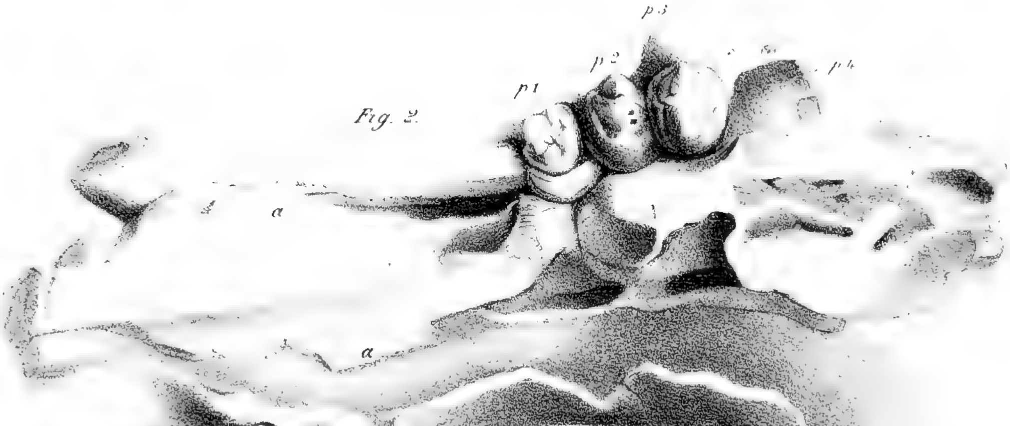


Fig. 2.



Lith. of G & W Endicott New York

Fig 4

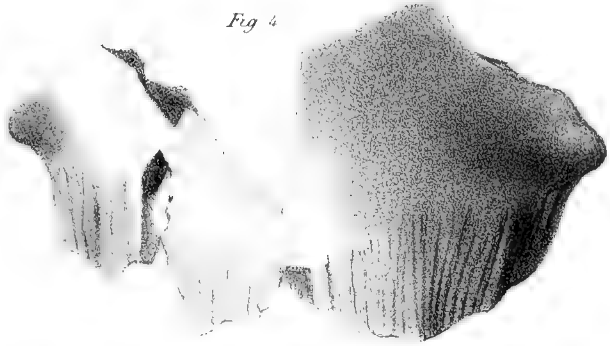


Fig 6.

Fig 5. A.

Fig 4.

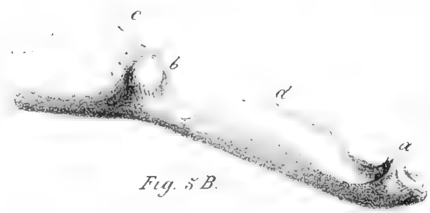


Fig. 5 B.

Lith. of G. S. [illegible] New York

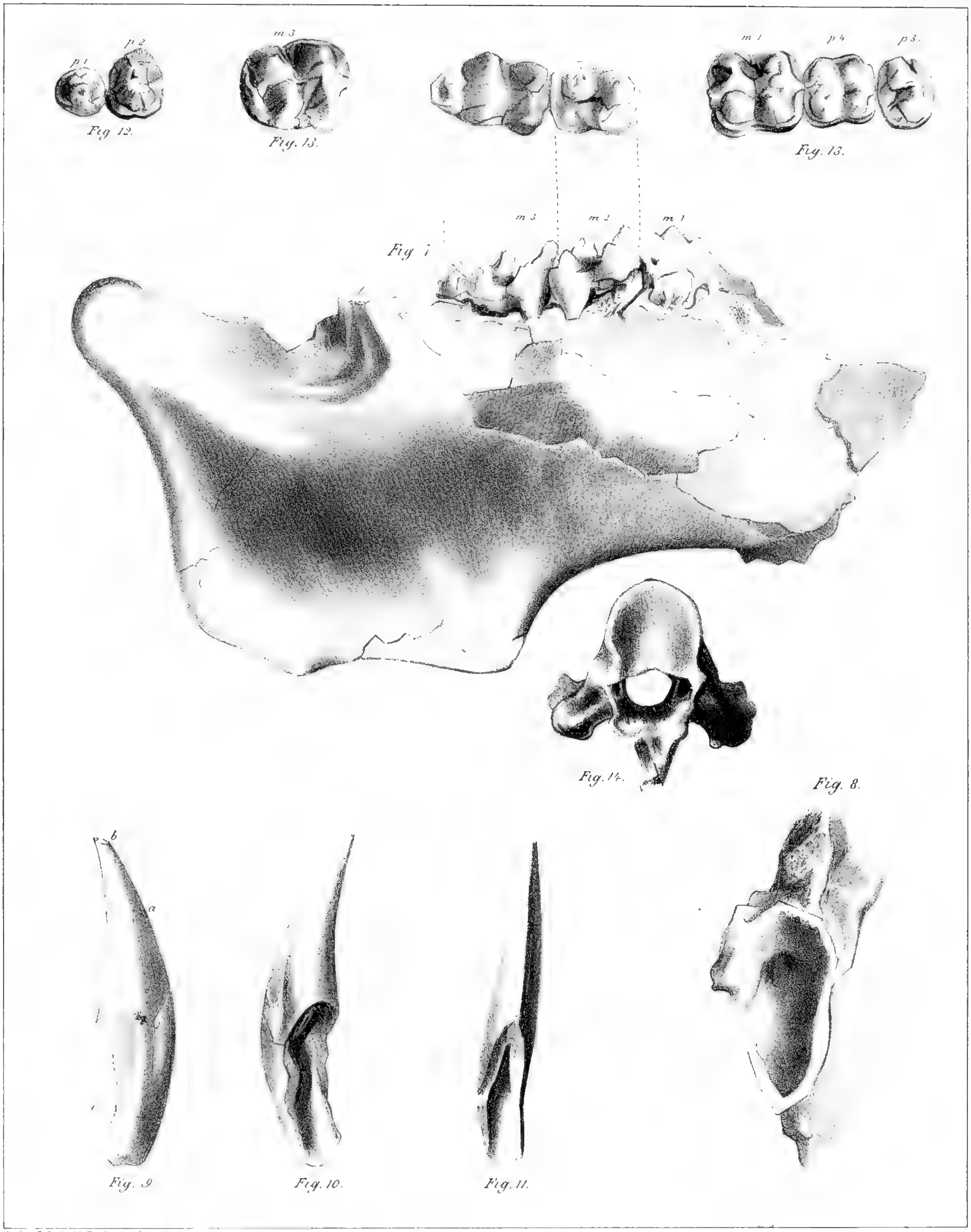


Fig. 12. Fig. 13. Fig. 13. Fig. 1. Fig. 14. Fig. 8. Fig. 9. Fig. 10. Fig. 11.

Lith. of G. & W. Endicott, New York

PLATE 4.

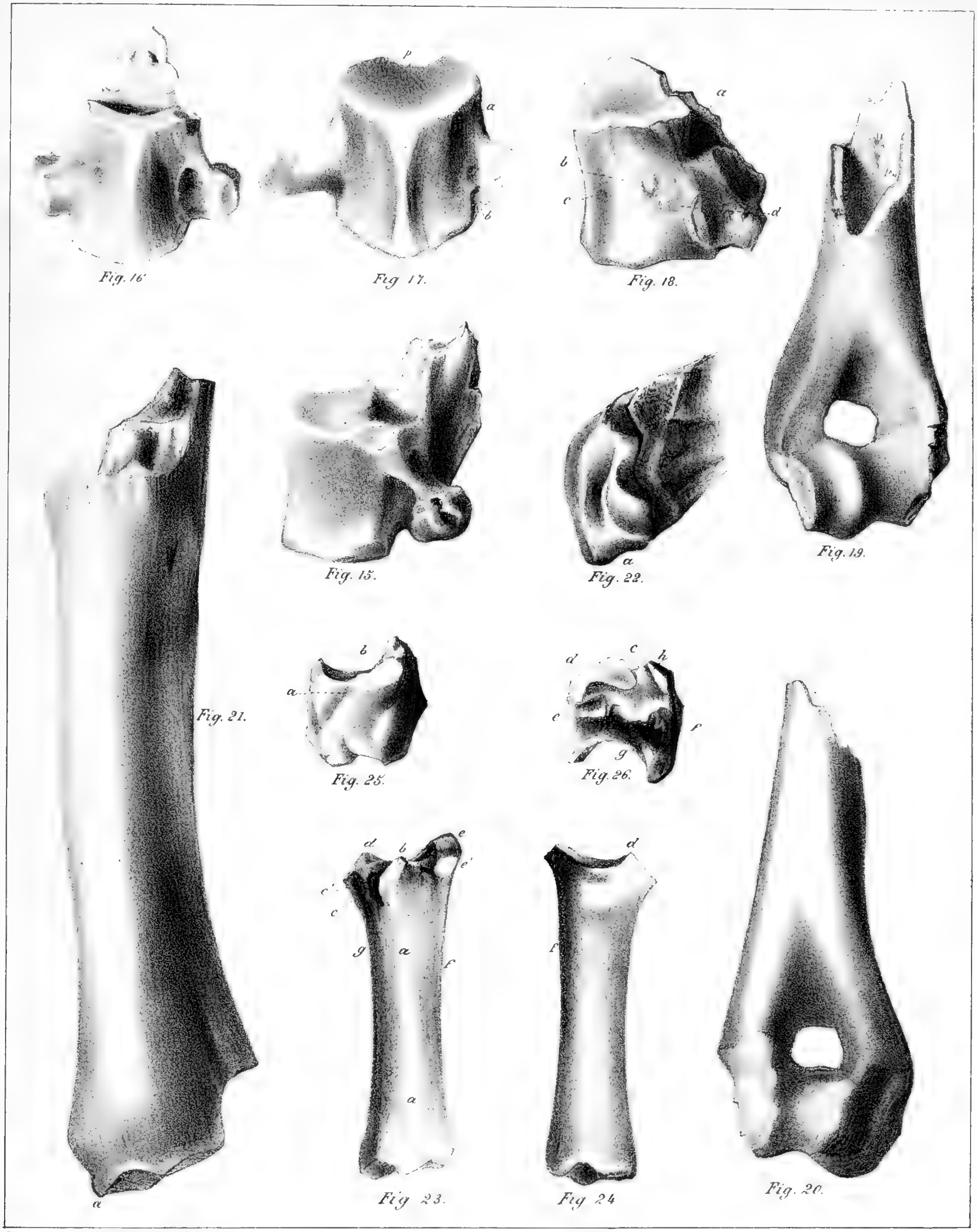


Fig. 16. Fig. 17. Fig. 18. Fig. 15. Fig. 22. Fig. 19. Fig. 21. Fig. 25. Fig. 26. Fig. 23. Fig. 24. Fig. 20.

Lith. of G & W Endicott New York.

APPENDIX.

Report on the Discovery and Name of an Eighth Satellite of Saturn.

(*Read November* 8, 1848.)

THE Committee to whom was referred the subject of the name proper to be given to the eighth satellite of Saturn, recently discovered at the Observatory in Cambridge, have attended to that duty, and beg leave to submit the following report:—

This important discovery, which was made by the Messrs. Bond, at the Observatory in Cambridge, on the 16th of September, was first announced to the public in a letter of the 25th instant, addressed to the President of the University, which was published on the 27th instant in the *Boston Daily Advertiser*. Copies of this letter were transmitted to London, Altona, and Paris, by the steamer of the 27th October.

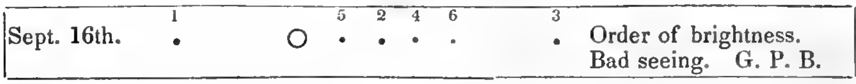
The great interest attaching to this discovery has induced the committee to submit to the Academy, as a part of their report, the following detailed account, with which they have been kindly furnished by Mr. Bond.

On the evening of the 15th September, in observing Saturn and his satellites, an object was noticed by Mr. G. P. Bond, which

was recorded as a satellite or star. The following diagram shows its position at the time: —

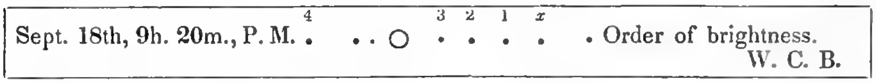
x is the object referred to.

On the 16th of September the new satellite was distinctly seen. It was noticed by Mr. George P. Bond as a point of light resembling a star of the seventeenth magnitude, in the plane of Saturn's ring, between Iapetus and Titan. It was entered by him in his diagram of the satellites as follows: —

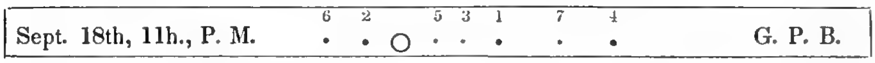


6 is the new satellite.

On the 18th it was again seen, similarly situated, and was recorded by both the Messrs. Bond, with a doubt expressed of its character.



x is the new satellite.



7 is the new satellite.

The further account of the discovery is given in the words of Mr. Bond, as contained in a letter of the 17th October to Mr. J. R. Hind, Foreign Secretary of the Royal Astronomical Society.

"The recurrence of nearly the same appearance on the 19th induced us to apply the micrometer, with which we obtained the

following measures from the object in question, which, for convenience, we shall designate by x.

1848.

" Sept. 19th, at 9h. 40m.	x precedes Iapetus	137″	Measured in the direction of the plane of the ring.
	Iapetus precedes star	344″	
" 12h. 0m.	x precedes Iapetus	141″	
	Iapetus precedes same star	366″	
" 13h. 15m.	x precedes Iapetus	143″	
	Iapetus precedes same star	375″	

" These measures indicated that the suspected body partook of the retrograde motion of Saturn.

" ' Sept. 19th, at 13h. 30m. x follows Saturn's centre 256″, in the direction of the plane of the ring.'

" A map of the stars in the path of Saturn for the two following nights was made, as a security against mistakes.

" The evening of the 20th proved cloudy.

" On the 21st the new satellite was compared with a star following it near the plane of the ring: —

Sept. 21st, 11h. 34m.,	Distance of x from the star,	276″.
12h. 11m.,	" " "	284″.
12h. 57m.,	" " "	293″.

And the distance of x from the centre of Saturn was found to be,

Sept. 21st, at 12h. 30m.,	x following Saturn	220″	1 measure.
" 22d, at 10h. 30m.,	" "	192″	5 "
" 23d, at 9h. 5m.,	" "	145″	5 "
" 28th, at 9h. 0m.,	x *preceding* Saturn	156″	5 "

" On each of these nights, with the exception of the 22d, the observations were continued long enough to identify the satellite by its motion.

" The presence of the moon prevented our obtaining further observations of the new satellite till the 13th of October, although we lost much time in observing accidental stars, which

could only be distinguished from the satellite by their not partaking of the motion of Saturn.

Oct. 13th, 7h. 40m., x follows Saturn's centre 202″.
" 14th, 7h. 0m., " " 152″.

"The motion of x among the stars was sensible in three hours.

Oct. 15th, 9h. 35m, x follows Saturn's centre 92.4″.

"The foregoing positions are approximately satisfied by a periodic time of twenty-one days.

"The orbit is nearly coincident with the plane of the ring."

In the letter of Mr. Bond addressed to Mr. Everett, above referred to, it is stated, that the light of the newly discovered satellite is fainter than that of the two interior satellites discovered by Sir William Herschel in 1789, which have ever been spoken of by observers as objects beyond the reach of any but the most powerful instruments. The discovery of the Messrs. Bond is, therefore, peculiarly satisfactory, as a test of the capacity of the new telescope at Cambridge, toward the purchase of which the Academy has contributed.

While this addition to the planetary system is justly to be regarded in itself as an event of high interest in astronomical science, it is rendered peculiarly so by the fact, that the same discovery was made almost at the same time by Mr. Lassell, at Starfield, near Liverpool. The committee have been permitted to incorporate in their report the following copy of a letter from this distinguished observer to Mr. Bond.

"Starfield, Liverpool, 30th September, 1848.

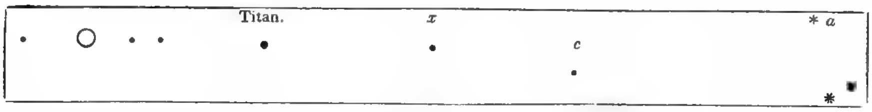
"Dear Sir, — I have the pleasure to inform you, that I have discovered an eighth satellite of the planet Saturn.

"In relating to you the mode of its discovery, I shall, in speak-

ing of Saturn's satellites, employ the proper names given to them by Sir John Herschel in his Cape Observations, namely, Mimas, Enceladus, Tethys, Dione, Rhea, Titan, and Iapetus, beginning with the closest, and proceeding in order of distance from their primary.

"On the 18th instant, while surveying the planet and looking for Iapetus, I observed *two stars* near the situation where I expected him to be. Not being certain which of these was he, I made a careful drawing of their situation with respect to some neighbouring fixed stars, of which the following is a copy.

"On the 19th instant, I was surprised to find that *both* stars had moved away from the fixed star *a*, as shown in the following diagram, *x* still remaining in the line of the satellites interior to



itself, while *c* had gone northward. A consideration of this appearance suggested the conviction that *x* must be a new satellite, *c* being thus proved to be Iapetus. I therefore immediately proceeded to take differences of A. R. between *x* and *a* and between *c* and *a*, with a view to verify the conjecture, and found that in 2.6 hours *x* had moved westward $2^s.46$, and that in 1.4 hours *c* had also moved westward $1^s.27$, establishing the fact that both stars were in motion. It is true that these differences do not correspond precisely with the orbital motion of Saturn, but I think they are not greater than can be well accounted for by

reasonable errors of observation during so short a period. Moreover, the point a being precisely in the line of the interior satellites, I took micrometrical measurements of his position with respect to the others at two epochs, differing four hours, and was perfectly satisfied that, during that interval, no perceptible change whatever in his position took place. As the motion of Saturn southwards during this interval would amount to 18″, it must have left the point x obviously behind, if it had been a fixed star. I could not then escape the conclusion that x is a new satellite of the planet.

"The 21st and 22d have been the only evenings since the 19th on which any observation could be got; it was then approaching Saturn. A season of cloudy weather has now set in, which is very unfortunate, as another clear night would have enabled me to ascertain something respecting the satellite's period. In conformity with Sir J. Herschel's nomenclature of the older satellites, I have proposed to call this *Hyperion*."

It will appear from the comparison of dates in the preceding accounts of the observations of Mr. Lassell and the Messrs. Bond, that the discovery of the new satellite by these eminent observers was nearly simultaneous. It was first noticed by the Messrs. Bond on the 16th, and by Mr. Lassell on the 18th of September, and the discoveries had been publicly announced in each country before the accounts from the other had been received. This circumstance leaves to each astronomer the credit of an original discovery. It is unnecessary to state that nothing but an instrumental power of the highest order, applied with consummate skill, would have sufficed for its achievement.

The first discovery of a satellite of Saturn was made by Chris-

tian Huyghens, in Holland, who is also entitled to the credit of first ascertaining the true nature of Saturn's ring.* On the 25th of March, 1655, while observing the ring of Saturn with a twelve-foot telescope, Huyghens's attention was attracted to the appearance of a star, which, carefully observed at the time and on the following evening, was evidently found to have changed its absolute place in the heavens, and to have shared the retrograde motion of the planet. These observations were continued every night, and on the 3d of April the new star was found on the other side of the planet.

The uncertainty, which still hung over many of what are now the most familiar facts in the solar system, led the astronomers of this period, instead of hastening with the utmost promptness to give their discoveries to the world, either wholly to suppress them, for a considerable time, or to communicate the discovery to some friend, wrapped up in the form of an anagram. Having repaired to Paris shortly after the discovery of a satellite of Saturn, and having there communicated it to his scientific friends, they advised him to make it public, which he did on the 5th of March, 1656, with an hypothesis explaining the other phenomena of Saturn, the latter, however, "*confuso elementorum quibus scribebatur ordine.*" In 1659 he thought the time had come for an ampler treatise on the subject, and accordingly prepared his *Systema Saturnium*,† where the gradual steps of his discovery and his entire system of Saturn are set forth. This interesting tract is dedicated to Prince Leopold of Tuscany, and in

* On the history of the discovery of Saturn's satellites, see *Astronomie par Lalande*, III. p. 202, and Smyth's *Celestial Cycle*, I. p. 197.

† *Christiani Hugenii Systema Saturnium, sive de causis mirandorum Saturni Phænomenôn et comite ejus Planeta novo.* Hagæ-Comitis, 1659.

the dedication, the confident opinion is expressed by Huyghens, that this satellite, being the twelfth planetary body in the solar system, fills up the number of bodies belonging to it, "*quo majorem post hac repertum non iri, prope est ut confirmare audeam.*" Such was the bold prediction adventured by Huyghens, on the ground of the supposed admirable qualities of the number *twelve.* In less than two centuries which have since elapsed, the number of planetary bodies (if we allow two satellites to Neptune) has been increased to thirty-eight, with a prospect of a future indefinite multiplication, bounded only by the improvements which may hereafter be made in the telescope.

Huyghens's satellite is by far the brightest of the Saturnian group, and the sixth in order from the primary. Its period is about fifteen days twenty-two hours, and in the nomenclature adopted by Sir John Herschel, the convenience of which has been so signally shown on occasion of the present discovery, it has received the name of *Titan.*

Toward the end of October, 1671, Dominique Cassini discovered the exterior satellite of the whole group, usually called the fifth in number, but now ascertained to be the eighth in order from the primary.* This discovery was made at Paris with a telescope of seventeen feet. It has a period of above seventy-nine days, and is called by Sir John Herschel *Iapetus.* On the 23d of December of the following year (1672), Cassini, making use of telescopes of thirty-five and seventy feet in length, discovered what used to be called the third satellite of Saturn; being the fifth from the primary. Its period is of four and a half days, and it is called *Rhea* by Sir John Herschel.† In 1684, Cassini discovered the fourth and fifth of the old enumeration, the third and fourth

* *Journal des Savans de l'An* 1677, p. 88. † *Ditto de l'An* 1686, p. 139.

in order from the primary. The first of these was computed by Cassini to have a period of one day and twenty-one hours, and the second of two days and seventeen hours. They are the *Tethys* and *Dione* of Sir John Herschel. Cassini employed for their discovery lenses arranged without tubes at enormous focal distances, not less than 155 and 220 Parisian feet. In his memoir in the *Journal des Savans* for 1686, he says, — "Il nous a été facile de voir par ces différents sortes de verres ces deux satellites, après avoir trouvé les règles de leur mouvement, qui nous ont fait regarder avec une attention plus particulière aux lieux où ils doivent être."

These large object-glasses were placed, says Cassini, sometimes on the top of the observatory, sometimes on a large pole, and sometimes on a wooden tower transported by order of the king, for this purpose, from Marly to the terrace of the observatory. They were afterwards inclosed in tubes.

The progress of astronomical observation, from this clumsy and helpless machinery to the parallactic movement of Fraunhofer, represents, by a very distinct scale of improvement, the advancement of modern science. Although Huyghens had at first been led to adventure the prediction, that his satellite completed the Saturnian group, he lived to see it increased by the four discovered by Cassini. In the second book of his *ΚΟΣΜΟΘΕΩΡΟΣ*, addressed to his brother, having alluded to the four satellites discovered by Cassini, he says, — "Imo præter harum numerum alias quoque vel unam vel plures latere suspicari licet, nec deest ratio. Cum enim inter extremas duas, spatium amplius pateat quam pro distantiis cæterarum, posset hoc insidere sextus satelles,

vel etiam ultra quintum alii circumvagari, qui propter obscuritatem nondum sint visi." *

As Galileo had given the names of the "Medicean stars" to the satellites of Jupiter, in honor of the liberal prince and family reigning at Florence, Cassini proposed to call the satellites of Saturn "Astra Lodoicea," in honor of Louis XIV., under whose reign and patronage they were discovered. But posterity has rejected these and all other attempts to affix contemporary names to the newly discovered planetary bodies.

The existence of Cassini's four satellites of Saturn was almost doubted in England, till the Astronomer Pound set up at Wansted a telescope of 123 feet focal distance, presented by Huyghens to the Royal Society and still in their possession. This took place in 1718.† The improvements soon made by Bradley in the construction of the telescope brought these satellites within the range of observation by instruments of reasonable dimensions. Captain Smyth quotes a remark from an astronomical work of Mr. J. Harris, F. R. S. in 1729, to this effect, that it is "highly probable that there may be more satellites than the five moving round this remote planet: but their distance is so great, and their light may be so obscure, as that they have hitherto escaped our eyes and perhaps may continue to do so for ever; for I don't think that our telescopes will be much further improved"! ‡

In 1789 Sir William Herschel completed his forty-foot reflector. He had suspected the existence of a sixth satellite as early as the

* *Christiani Hugenii Cosmotheoros, sive de Terris cœlestibus earumque ornatu conjecturæ ad Constantinum Hugenium fratrem, Gulielmo III. Magnæ Britanniæ Regi a secretis*, Lib. II. Oper. I. p. 698.

† *Abridgment of the Transactions of the Royal Society*, IV. p. 322.

‡ *Celestial Cycle*, I. p. 198.

19th of August, 1787, but was prevented by other researches from verifying his observation. The final discovery may be stated in his own words: — "In hopes of great success with my forty-feet speculum, I deferred the attack upon Saturn till that should be finished; and having taken an early opportunity of directing it to Saturn, the very first moment I saw the planet, which was the 28th of last August (1789), I was presented with a view of six of its satellites, in such a situation, and so bright, as rendered it impossible to mistake them or not to see them. The retrograde motion of Saturn amounted to nearly 4½ minutes per day, which made it very easy to ascertain whether the stars I took to be satellites really were so; and in about two hours and a half, I had the pleasure of finding that the planet had visibly carried them all away from their places. I continued my observations constantly, whenever the weather would permit, and the great light of the forty-feet speculum was now of so much use, that I also, on the 17th of September, detected the seventh satellite when it was at its greatest preceding elongation." *

Of the two satellites discovered by his father, Sir John Herschel thus expresses himself: — "The two interior satellites, which just skirt the edge of the ring and move exactly in its plane, have never been discerned but with the most powerful telescopes which human art has yet constructed, and then under peculiar circumstances. At the time of the disappearance of the ring (to ordinary telescopes), they have been seen † threading like beads the almost infinitely thin fibre of light to which it is then reduced, and for a short time advancing off it, at either end, speedily to return, and hastening to their habitual concealment." ‡

* *Transactions of the Royal Society*, 1790, p. 10.

† "By my father, in 1789, with a reflecting telescope of four feet aperture."

‡ Sir John Herschel's *Treatise on Astronomy*, § 468.

The periodical time of the innermost of Sir W. Herschel's satellites is but twenty-two hours, and of his second satellite one day and eight hours. Sir John Herschel proposes to call the former Mimas and the latter Enceladus.

It will be recollected that the periodical time of the new satellite is approximately estimated by Mr. Bond at twenty-one days. As the period of Titan is fifteen days and twenty-two hours, and that of Iapetus seventy-nine days, it may be reasonably conjectured that one, perhaps more than one, satellite remains yet undiscovered, to fill up the disproportioned space.

Such was the Saturnian system, as far as the satellites are concerned, till the recent discovery. Some confusion existed in their designation. They have hitherto been designated numerically, nearly, but not quite, in the order of discovery; that is to say, the third from the primary has been called number one, and so on to the exterior satellite, which has been called number five. The second from the primary (being Sir William Herschel's first discovery) has been called number six, and the interior satellite number seven. In this nomenclature Huyghens's satellite, the largest and first discovered, is numbered fourth, which represents neither the order of discovery nor of place in relation to the primary.

To avoid the confusion of this system, it had latterly been usual to designate the group numerically, calling the interior satellite number one, and so on regularly through the seven; but this improved nomenclature was not yet universally adopted.

In order to provide an effectual remedy for the uncertainty of the former modes of designation, Sir John Herschel, in his recent great work on the Cape Observations,* has made the happy rec-

* *Results of Astronomical Observations made during the Years* 1834, 5, 6, 7, 8, *at the Cape of Good Hope*, &c., by Sir John F. W. Herschel. 4to. 1847.

ommendation of a separate name for each satellite. The names proposed by him are drawn from the mythological family of Saturn.* After enumerating them he adds: — "Should an eighth satellite exist, the confusion of the old nomenclature will become quite intolerable."

The names selected by Sir John Herschel are the following: —

"The exterior satellite, discovered by Cassini,	Iapetus.
The bright satellite, discovered by Huyghens,	Titan.
The exterior of the three satellites discovered by Cassini,	Rhea.
The intermediate of these three,	Dione.
The interior of them,	Tethys.
The exterior of the two discovered by Sir W. Herschel,	Enceladus.
The interior and smallest of all,	Mimas."

The discovery of an eighth satellite, alluded to by Sir John Herschel as possible, having now been effected by the admirable instruments and not less admirable skill of the Messrs. Bond and Mr. Lassell, it becomes absolutely necessary to adopt some convenient system of names for the separate members of this large planetary family. The names proposed by Sir John Herschel were spontaneously adopted by the Messrs. Bond and Mr. Lassell; and it now only remains to appropriate a name to the satellite discovered by themselves.

* Sir John Herschel thus states the considerations which governed his selection of names: — "As Saturn devoured his children, his family could not be assembled around him, so that the choice lay among his brothers and sisters, the Titans and Titanesses. (*Vide* Lempriere.) The name of Iapetus seemed indicated by the obscurity and remoteness of the exterior satellite, Titan by the superior size of the Huyghenian, while the three female appellations class together the three intermediate Cassinian satellites. The minute interior ones seemed appropriately characterized by a return to male appellations, chosen from a younger and inferior (though still superhuman) brood." — p. 415.

This subject was brought to the consideration of the Academy, in a short paper read at the last informal meeting by the chairman of the present committee. On this occasion he expressed himself as follows: — "Established usage in reference to the designation of the heavenly bodies and the symmetry of Sir John Herschel's nomenclature of the satellites of Saturn require the adoption of some name drawn from heathen mythology. Sir John Herschel has confined himself to the family of Saturn, and among the yet unappropriated names in this family are Prometheus, Hyperion, and Hesperus. As the new satellite stands next to Iapetus, *Prometheus*, the son of Iapetus, ('Audax Iapeti genus,') might seem an appropriate name. If it were deemed more consonant to uniformity to place another brother of Saturn between Iapetus and Titan, *Hyperion* answers that condition, and is in other respects a well-sounding name. I should incline to prefer *Hesperus*, another son of Iapetus, as shorter and as having some appropriateness to a satellite discovered on the Western Continent, were it not that Hesper is employed by the poets for another purpose."

This subject having, after some conversation, at the last meeting of the Academy, been referred to the present committee, an early opportunity was taken of consulting Mr. Bond as to the choice of a name for the new satellite, he being considered by the committee as the individual best entitled to decide the matter. He preferred, with characteristic modesty, to withhold the expression of any wish on that point, till it should be ascertained from Europe whether he was the first discoverer of the satellite. The next steamer brought the intelligence of Mr. Lassell's discovery, with a priority of two days on the part of the Messrs. Bond. It also appeared that Mr. Lassell had proposed to call the new satellite "Hyperion." As this name is recommended by the consideration above adverted

to, and Mr. Bond has expressed a decided preference for it, your committee strongly recommend it as the name of the new satellite.

The committee are happy to have it in their power to state to the Academy, that Mr. Bond is preparing a memoir, to be submitted to the Academy at a future day, containing in full the result of the observations of Saturn, his rings, and satellites, made at the Observatory in Cambridge during the past year.

Your committee were further instructed to inquire into the practicability of adopting an appropriate and convenient notation for the satellites of Saturn; the want of which is sensibly felt in all discussions of the theory of the Saturnian system. The committee have given some consideration to this subject, but are not prepared to submit any report upon it to the Academy. It is the intention of one of the members of the committee, (Professor Peirce,) to engage in a full investigation of the satellites of Saturn, in connection with which this point will receive due consideration.

All which is respectfully submitted.

For the Committee,

EDWARD EVERETT, *Chairman.*

Cambridge, 8th November, 1848.

NOTE. — The following is the letter of Mr. Bond, referred to on page 275.

" Observatory, Cambridge, September 25th, 1848.

" DEAR SIR, — On the evening of the 16th of this month, a small star was noticed, situated nearly in the plane of Saturn's ring, and between the satellites Titan and Iapetus. It was regarded at the time as accidental. It was, however, recorded, with an estimated position in regard to Saturn.

"The next night favorable for observation was the 18th, and while comparing the relative brightness of the satellites, the same object, similarly situated in regard to the planet, was again noticed, and its position more carefully laid down. But still, at the time, we scarcely suspected its real nature.

"From accurate measurement on the evening of the 19th, the star being found to partake of the retrograde motion of Saturn, that portion of the heavens towards which the planet was approaching was carefully examined, and every star near its path for the two following nights laid down on a diagram, and micrometric measures of position and distance with objects in the neighbourhood were taken.

"The evening of the 20th was cloudy. On the 21st, the new satellite was found to have approached the primary, and it moved sensibly among the stars while under observation. Similar observations were repeated on the nights of the 22d and 23d. Its orbit is exterior to that of Titan. It is less bright than either of the two inner satellites discovered by Sir William Herschel.

"Respectfully,

[Signed,] "W. C. BOND.

"PRESIDENT EVERETT."

THE foregoing report was read at the Quarterly Meeting of the American Academy of Arts and Sciences, held this day in Boston, and ordered to be printed as an Appendix to the forthcoming volume of the Memoirs.

A. A. GOULD, *Recording Secretary.*

Boston, 8th November, 1848.